(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 100 107 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
16.05.2001 Bulletin 2001/20

(51) Int Cl.7: H01J 7/18, H01J 29/94

(21) Application number: 00403155.5

(22) Date of filing: 13.11.2000

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 12.11.1999 JP 32330199
15.11.1999 JP 32408899
31.08.2000 JP 2000262754

(71) Applicant: SONY CORPORATION
Tokyo (JP)

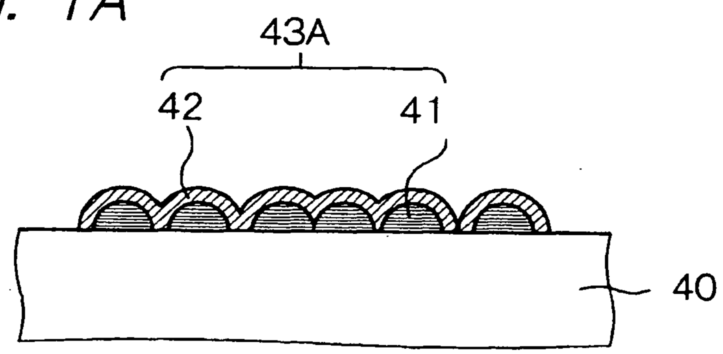
(72) Inventors:
- Morikazu, Konishi, c/o Sony Corporation
Shinagawa-ku, Tokyo (JP)
- Ichiro, Saito, c/o Sony Corporation
Shinagawa-ku, Tokyo (JP)
- Masakazu, Muroyama, c/o Sony Corporation
Shinagawa-ku, Tokyo (JP)

(74) Representative: Thévenet, Jean-Bruno et al
Cabinet Beau de Loménie
158, rue de l'Université
75340 Paris Cédex 07 (FR)

(54) Getter, flat-panel display and method of production thereof

(57) A getter (43A) comprising a support member (41) which is formed on a substratum (40) and which has a convexo-concave surface or is constituted of a porous material member, and a gas-trapping layer (42) formed on the support member in conformity with the surface of the support member.

Fig. 1A



EP 1 100 107 A2

Description

BACKGROUND OF THE INVENTION AND RELATED ART STATEMENT

[0001] The present invention relates to a getter, a flat-panel display and a method of producing the flat-panel display, and it relates particularly to a getter improved in gas trapping efficiency, a flat-panel display having such a getter and having a long lifetime and a high-quality image, and a method of easily producing such a flat-panel display.

[0002] In the field of displays used in television sets and information terminals, studies have been and are made on flat-panel displays as substitutes for conventional mainstream cathode ray tubes (CRT) for complying with demands for a decrease in thickness, a decrease in weight, an increase in a display area and higher fineness. As one type of the flat-panel displays, there is known a flat-panel display having two panels opposed to each other through a vacuum layer such as a cold cathode field emission display (FED: field emission display). In the cold cathode field emission display (to be sometimes referred to as "display" hereinafter), when a high electric field is applied to a top portion of, for example, a needle-shaped conductive or semi-conductive material, electrons pass through a potential barrier in the conductive or semi-conductive material at room temperature due to a quantum tunnel effect and are emitted from the top portion. This phenomenon is also called "field emission" or "cold-cathode emission".

[0003] Fig. 66 shows a conceptual exploded view of the above display. The display has a constitution in which a first panel P_1 (display panel) and a second panel P_2 are arranged so as to be opposed to each other through a vacuum layer and the first panel P_1 and the second panel P_2 are bonded to each other in their circumferential portions through a frame 24. In Fig. 66, section lines show bonding portions. Each of the first panel P_1 and the second panel P_2 is functionally largely classified into an effective field EF_1 or EF_2 (indicated by section lines) which has pixels arranged and works as an actual display portion and a non-effective field NE_1 or NE_2 which encompasses the effective field EF_1 or EF_2 and has peripheral circuits for selecting pixels, etc., formed thereon. For maintaining a vacuum degree of the vacuum layer, such a display has a getter 642 composed of a material capable of trapping residual gas in the vacuum layer. Generally, the getter 642 is disposed in the non-effective field of one of the panels P_1 and P_2. In the shown example, one or a plurality of through holes 640 are formed in the non-effective field NE_1 of the first panel P_1, a getter box 641 is disposed so as to close the through hole(s) 640 from an outside of the first panel P_1, and the getter 642 is held in the getter box 641. Another through hole 616 for vacuuming is provided in some other place of the non-effective field NE_1, and connected to the through hole 616a is a chip tube 617 which is used for sealing-off after vacuuming.

[0004] Fig. 67 shows a schematic partial end view of a configuration example of a display in which electron-emitting regions constituted of a plurality of cold cathode field emission devices (to be referred to as "field emission devices" hereinafter) are disposed in the effective field EF_1 of the first panel P_1 (also called "cathode panel").

[0005] The field emission devices shown in Fig. 67 are so-called Spindt-type field emission devices having a conical electron-emitting portion each. Such a field emission device comprises a supporting substrate 610, a cathode electrode 61 formed on the supporting substrate 610, an insulating layer 612 formed on the substrate 610 and the cathode electrode 611, a gate electrode 613 formed on the insulating layer 612, an opening portion 614 formed through the gate electrode 613 and the insulating layer 612, and a conical electron-emitting portion 615 formed on the cathode electrode 611 positioned in the bottom portion of the opening portion 614. Generally, an electrically conductive material layer which constitutes the cathode electrode 611 and has the form of a stripe (to be referred to as "electrically conductive material for a cathode electrode") and an electrically conductive material layer which constitutes the gate electrode 613 and has the form of a stripe (to be referred to as "electrically conductive material layer for a gate electrode") are formed in directions in which the projection images of these electrically conductive material layers cross each other at right angles. Generally, a plurality of the field emission devices are arranged in a region corresponding to a portion where the projection images of the above electrically conductive material layers in the form of stripes overlap (one region corresponds to a region of one pixel and refers to an electron-emitting region). Further, such electron-emitting regions are generally arranged in the effective field EF_1 of the first panel P_1 in the form of a two-dimensional matrix.

[0006] The second panel P_2 (also called "anode panel") comprises a substrate 20, fluorescent layers 21 (fluorescent layers 21R, 21G, 21B) formed on the substrate 20 in a predetermined pattern and an anode electrode 23 formed on the entire surface on the fluorescent layers 21. A black matrix 22 is formed on the substrate 20 between one fluorescent layer and another fluorescent layer.

[0007] A relatively negative voltage is applied to the cathode electrode 611 from a control circuit 30, a relatively positive voltage is applied to the gate electrode 613 from a scanning circuit 31, and a positive voltage higher than the voltage to the gate electrode 613 is applied to the anode electrode 23 from an accelerating power source 32. When such a display is used for displaying, a control signal (video signal) is inputted to the cathode electrode 611 from the control circuit 30, and a scanning signal is inputted to the gate electrode 613 from the scanning circuit 31. Due to an electric field generated when a voltage is applied between the cathode electrode 611 and the gate electrode 613, electrons are emitted from the electron-emitting portion 615 and are attracted to the anode electrode 23 to collide with the fluorescent layer 21. As a result, the fluorescent layer 21 is excited to emit light, whereby an intended image can

be obtained. That is, the operation of the above display is in principle controlled by a voltage applied to the gate electrode 613 and a voltage applied to the electron-emitting portion 615 through the cathode electrode 611.

[0008] When the fluorescent layer 21 is irradiated with electrons in the above display having the field emission devices, water and/or carbon dioxide caught on the surface of, or inside, the fluorescent layer 21 acquire energy and are dissociated or released into the vacuum layer in the form it already has or in the form of decomposition products such as carbon monoxide, oxygen, hydrogen and the like. The above gas which is dissociated or released into the vacuum layer will be generically referred to as "released gas" for convenience. When the released gas is adsorbed on the surface of the electron-emitting portion 615 or when the adsorbed released gas is re-dissociated from the surface of the electron-emitting portion 615, the work function of the electron-emitting portion 615 changes due to adsorption or re-dissociation, and an a result, a current of emitted electrons varies to cause noises. For example, it is known that when oxygen gas is adsorbed on the surface of the electron-emitting portion 615 composed of tungsten, the work function of the surface of the electron-emitting portion 615 increases by approximately 1 or 2 eV, so that the current density of emitted electrons decreases to approximately 10 % to 1 % based on the counterpart in a normal state. Further, the released gas may be ionized to form a positive ion in the vacuum layer. In this case, the positive ion is accelerated toward the electron-emitting portion 615 due to the positive voltage applied to the anode electrode 23 through the accelerating power source 32, and the positive ion sputters the electron-emitting portion 615 to deteriorate them.

[0009] The above positive ion or electrons can further enter the gate electrode 613 or the insulating layer 612 located near the electron-emitting portion 615. As a result, water, carbon dioxide, etc., adsorbed on or occluded in the gate electrode 613 or the insulating layer 612 are dissociated or released. For this reason, the vacuum degree near the electron-emitting portion 615 is temporarily degraded (i.e.. an increase in pressure), and local discharge may take place between the gate electrode 613 and the electron-emitting portion 615. If the local discharge takes place once, sputtering of the members, which constitute the field emission device, near the electron-emitting portion 615, an increase in the temperature of the members and further generation of released gas proceed like a chain reaction and the discharge is amplified, and in a worst case, the electron-emitting portion 615 is damaged and electrons can be no longer emitted. As a result, the lifetime of the display is degraded.

[0010] The above getter 642 is provided for avoiding the above disadvantages caused by the released gas. The getter 642 is composed of a chemically highly active material such as barium, magnesium, zirconium or titanium, and traps the gas until an equilibrium state dependent upon a partial pressure of the released gas in the atmosphere is reached. Further, gas molecules once trapped are diffused into the getter 642 and form a solid solution with the material thereof, so that the trapped gas is generally not re-released in any case.

[0011] While the getter 642 has the above excellent gas trapping performance, it cannot be said that the getter 642 exhibits its gas trapping performance effectively on all the field emission devices in the effective field since it is disposed in the non-effective field of the display. That is, in most of the field emission devices other than those field emission devices located near the getter 642, the getter 642 cannot be expected to trap the released gas immediately when the released gas increases a pressure near the field emission devices 615, so that it is difficult to prevent the local discharge effectively.

[0012] Fig. 68 schematically shows a pressure distribution example in the vacuum layer when gas molecules are released from an electron-emitting portion 615. For example, it is supposed that gas molecules are released from a gate electrode 613 or the insulating layer 612 in an arbitrary position D near the electron-emitting portion 615 in the vacuum layer. In this case, the pressure in the position D where the gas molecules are released can locally increase, for example, up to about 1 Pa, and discharge may take place. If the position D is near the getter box 641, the getter 642 can prevent an increase in pressure and the discharge in the vacuum layer with its gas trapping function. However, the gas molecules are released in the position D apart from the getter box 641 as shown in Fig. 68, the gas trapping function of the getter 642 is poor, so that there is liable to be caused a vicious circle in which the discharge and the release of gas molecules take place like a chain reaction.

OBJECT AND SUMMARY OF THE INVENTION

[0013] It is therefore an object of the present invention to provide a flat-panel display which can attain a long lifetime and a high-quality image by efficient gettering.

[0014] It is another object of the present invention to provide a method of easily producing the above flat-panel display.

[0015] It is still another object of the present invention to provide a getter improved in gas trapping efficiency.

[0016] The getter of the present invention for achieving the above object comprises a support member which is formed on a substratum and which has a convexo-concave (or rough, uneven or irregular) surface or is constituted of a porous material member, and a gas-trapping layer formed on the support member in conformity with the surface of the support member.

[0017] In the getter of the present invention, the gas-trapping layer is formed in conformity with the surface of the

support member, so that the gas-trapping layer has an increased surface area as compared with a case where the gas-trapping layer has a flat surface, and that the probability of contact to gas in an external environment is high. When the getter of the present invention is applied to the flat-panel display of the present invention to be described later, the external environment corresponds to a vacuum layer, and the gas corresponds to the released gas from internal constituting members which face the vacuum layer. The getter of the present invention has excellent gas trapping efficiency over conventional getters, and can work to maintain the vacuum degree at a high level for a long period of time. The term "trapping" includes absorption, adsorption, occlusion and sorption. In the getter of the present invention, further, the substratum is not at all critical so long as it can mechanically stably support the support member.

[0018] The flat-panel display of the present invention for achieving the above object is a flat-panel display comprising a first panel and a second panel which are opposed to each other through a vacuum layer and have effective fields where pixels are arranged, wherein the effective field of at least one of the first panel and the second panel is provided with a getter for maintaining a vacuum degree of the vacuum layer.

[0019] In a specific constitution of the flat-panel display of the present invention, the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and each of the cold cathode field emission devices comprises;

(A) an insulating layer formed on a supporting substrate,
(B) a gate electrode formed on the insulating layer,
(C) an opening portion which penetrates through the gate electrode and is formed in the insulating layer, and
(D) an electron-emitting portion formed in the opening portion, and

preferably, the above getter is provided on the gate electrode and/or on the insulating layer between one gate electrode and another gate electrode which are adjacent to each other.

[0020] The flat-panel display having the above constitution will be referred to as "flat-panel display according to the first constitution of the present invention". The flat-panel display according to the first constitution of the present invention is a so-called cold cathode field emission display.

[0021] In another specific constitution of the flat-panel display of the present invention, the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and each of the cold cathode field emission devices comprises:

(A) an insulating layer formed on a supporting substrate,
(B) a gate electrode formed on the insulating layer,
(C) a second insulating layer formed on the gate electrode and the insulating layer,
(D) a focus electrode formed on the second insulating layer,
(E) an opening portion which penetrates through the focus electrode, the second insulating layer and the gate electrode and is formed in the insulating layer, and
(F) an electron-emitting portion formed in the opening portion, and

preferably, the above getter is provided on the focus electrode and/or on the second insulating layer between one focus electrode and another focus electrode which are adjacent to each other.

[0022] The flat-panel display having the above constitution will be referred to as "flat-panel display according to the second constitution of the present invention". The flat-panel display according to the second constitution of the present invention is a cold cathode field emission display having a focus electrode.

[0023] The focus electrode refers to an electrode which makes it possible to improve brightness and to prevent optical crosstalk between the adjacent pixels by converging the path of electrons emitted through the opening portion toward the anode electrode. In the case of a so-called high voltage type flat-panel display in which the anode electrode and the cathode electrode have a potential difference by the order of several kilovolts and the distance between these two electrodes is relatively large, the focus electrode is particularly effective. A relatively negative voltage is applied to the focus electrode from a focus power source. It is not necessarily required to provide one focus electrode per cold cathode field emission device. For example, the focus electrode is allowed to extend in a predetermined arrangement direction of the cold cathode field emission devices. In this case, a common focusing effect can be exerted on a plurality of the cold cathode field emission devices.

[0024] In the flat-panel display according to the first or second constitution of the present invention, the getter comprises a support member which has a convexo-concave surface or is constituted of a porous material member, and a gas-trapping layer formed on the support member in conformity with the surface of the support member. Preferably, the support member is formed on the gate electrode and/or on the insulating layer between one gate electrode and another gate electrode which are adjacent to each other, or it is formed on the focus electrode and/or on the second insulating layer between one focus electrode and another focus electrode which are adjacent to each other.

[0025] In another specific constitution of the flat-panel display of the present invention, the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and each of the cold cathode field emission devices comprises;

(A) an insulating layer formed on a supporting substrate,
(B) a gate electrode which is formed on the insulating layer and at least part of which is composed of a gas-trapping material,
(C) an opening portion which penetrates through the gate electrode and is formed in the insulating layer, and
(D) an electron-emitting portion formed in the opening portion, and

preferably, the gate electrode works as the above getter.

[0026] The flat-panel display having the above constitution will be referred to as "flat-panel display according to the third constitution of the present invention". The flat-panel display according to the third constitution of the present invention is a cold cathode field emission display.

[0027] In the flat-panel display according to the third constitution of the present invention, the gate electrode may have a single-layered structure composed of a gas-trapping material, or the gate electrode may have a stacked structure constituted, at least, of a first layer composed of an electrically conductive material or an electrically insulating material and a second layer composed of a gas-trapping material.

[0028] In another specific constitution of the flat-panel display of the present invention, the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and each of the cold cathode field emission devices comprises;

(A) an insulating layer formed on a supporting substrate,
(B) a gate electrode formed on the insulating layer,
(C) a second insulating layer formed on the gate electrode and on the insulating layer,
(D) a focus electrode which is formed on the second insulating layer and at least part of which is composed of a gas-trapping material,
(E) an opening portion which penetrates through the focus electrode, the second insulating layer and the gate electrode and is formed in the insulating layer, and
(F) an electron-emitting portion formed in the opening portion, and

preferably, the focus electrode works as the above getter.

[0029] The flat-panel display having the above constitution will be referred to as "flat-panel display according to the fourth constitution of the present invention". The flat-panel display according to the fourth constitution of the present invention is a cold cathode field emission display having a focus electrode.

[0030] In the flat-panel display according to the fourth constitution of the present invention, the focus electrode may have a single-layered structure composed of a gas-trapping material, or the focus electrode may have a stacked structure constituted, at least, of a first layer composed of an electrically conductive material or an electrically insulating material and a second layer composed of a gas-trapping material.

[0031] In another specific constitution of the flat-panel display of the present invention, the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and each of the cold cathode field emission devices comprises;

(A) a spacer disposed on a supporting substrate and composed of an electrically insulating material,
(B) a gate electrode constituted of a gas-trapping material layer which has a plurality of opening portions formed therein and at least part of which is composed of a gas-trapping material, and
(C) an electron-emitting portion formed on the supporting substrate, and

preferably, the gas-trapping material layer is fixed such that it comes in contact with the top surface of the spacer and that the opening portion is positioned above the electron-emitting portion.

[0032] The flat-panel display having the above constitution will be referred to as "flat-panel display according to the fifth constitution of the present invention". The flat-panel display according to the fifth constitution of the present invention is a cold cathode field emission display.

[0033] In the flat-panel displays according to the first to fifth constitutions of the present invention, the first panel is sometimes called a cathode panel, and the second panel is sometimes called an anode panel. In the flat-panel display according to the first constitution of the present invention, the gate electrode and/or the insulating layer between one gate electrode and another gate electrode which are adjacent to each other correspond to the substratum, and in the flat-panel display according to the second constitution of the present invention, the focus electrode and/or the second

insulating layer between one focus electrode and another focus electrode which are adjacent to each other correspond to the substratum.

[0034] The method of producing a flat-panel display, provided by the present invention, for achieving the above object is a method of producing the flat-panel display of the present invention. That is, it is a method of producing a flat-panel display comprising a first panel and a second panel which are opposed to each other through a vacuum layer, have effective fields where pixels are arranged, and are bonded to each other in circumferential portions thereof, the method including the step of forming a getter in the effective field of at least one of the first panel and the second panel.

[0035] In a specific constitution of the method of producing a flat-panel display, provided by the present invention, the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and the first panel can be produced by the steps of;

(a) forming an insulating layer on a supporting substrate,
(b) forming an electrically conductive material layer for a gate electrode on the insulating layer,
(c) forming a getter-forming layer on the electrically conductive material layer,
(d) patterning the getter-forming layer and the electrically conductive material layer to form a gate electrode having a getter formed on the top surface of the gate electrode,
(e) forming an opening portion at least in the insulating layer, and
(f) forming or exposing an electron-emitting portion in the opening portion.

[0036] The method of producing a flat-panel display, having the above constitution, will be referred to as the production method according to a first constitution of the present invention. The flat-panel display according to the first constitution of the present invention can be produced by the production method according to the first constitution of the present invention, and the gate electrode and the getter are formed by simultaneous patterning so as to have the same patterns.

[0037] In the production method according to the first constitution of the present invention, preferably, the step (c) of forming a getter-forming layer comprises (1) the step of forming a supporting member which has a convexo-concave surface or is constituted of a porous material member, on the electrically conductive material layer for a gate electrode, and (2) the step of forming a gas-trapping layer which is in conformity with the surface of the supporting member, on the supporting member.

[0038] In another specific constitution of the method of producing a flat-panel display, provided by the present invention, the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and the first panel can be produced by the steps of:

(a) forming an insulating layer on a supporting substrate,
(b) forming a gate electrode on the insulating layer,
(c) forming a second insulating layer on the insulating layer and the gate electrode,
(d) forming an electrically conductive material layer for a focus electrode on the second insulating layer,
(e) forming a getter-forming layer on the electrically conductive material layer,
(f) patterning the getter-forming layer and the electrically conductive material layer to form a focus electrode having a getter formed on the top surface of the focus electrode,
(g) forming an opening portion at least in the second insulating layer and in the insulating layer, and
(h) forming or exposing an electron-emitting portion in the opening portion.

[0039] The method of producing a flat-panel display, having the above constitution, will be referred to as the production method according to a second constitution of the present invention. The flat-panel display according to the second constitution of the present invention can be produced by the production method according to the second constitution of the present invention, and the focus electrode and the getter are formed by simultaneous patterning so as to have the same patterns.

[0040] In the production method according to the second constitution of the present invention, preferably, the step (e) of forming a getter-forming layer comprises (1) the step of forming a supporting member which has a convexo-concave surface or is constituted of a porous material member, on the electrically conductive material layer for a focus electrode, and (2) the step of forming a gas-trapping layer which is in conformity with the surface of the supporting member, on the supporting member.

[0041] In another specific constitution of the method of producing a flat-panel display, provided by the present invention, the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and the first panel can be produced by the steps of;

(a) forming an insulating layer on a supporting substrate,

(b) forming a gate electrode on the insulating layer,
(c) forming a getter on the gate electrode and/or on the insulating layer between one gate electrode and another gate electrode which are adjacent to each other,
(d) forming an opening portion at least in the insulating layer, and
(e) forming or exposing an electron-emitting portion in the opening portion.

[0042] The method of producing a flat-panel display, having the above constitution, will be referred to as the production method according to a third constitution of the present invention. The flat-panel display according to the first constitution of the present invention can be produced by the production method according to the third constitution of the present invention, and the gate electrode and the getter are formed in separate steps.

[0043] In the production method according to the third constitution of the present invention, preferably, the step (c) of forming a getter comprises (1) the step of forming a supporting member which has a convexo-concave surface or is constituted of a porous material member, on the gate electrode and/or on the insulating layer between one gate electrode and another gate electrode which are adjacent to each other, and (2) the step of forming a gas-trapping layer which is in conformity with the surface of the supporting member, on the supporting member. Except for a case where the getter is formed on the entire surface, the supporting member and the gas-trapping layer may be patterned to complete the getter after the step (2).

[0044] In another specific constitution of the method of producing a flat-panel display, provided by the present invention, the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and the first panel can be produced by the steps of:

(a) forming an insulating layer on a supporting substrate,
(b) forming a gate electrode on the insulating layer,
(c) forming a second insulating layer on the insulating layer and the gate electrode,
(d) forming a focus electrode on the second insulating layer,
(e) forming a getter on the focus electrode and/or on the second insulating layer between one focus electrode and another focus electrode which are adjacent to each other,
(f) forming an opening portion at least in the second insulating layer and in the insulating layer, and
(g) forming or exposing an electron-emitting portion in the opening portion.

[0045] The method of producing a flat-panel display, having the above constitution, will be referred to as the production method according to a fourth constitution of the present invention. The flat-panel display according to the second constitution of the present invention can be produced by the production method according to the fourth constitution of the present invention, and the focus electrode and the getter are formed in separate steps.

[0046] In the production method according to the fourth constitution of the present invention, preferably, the step (e) of forming a getter comprises (1) the step of forming a supporting member which has a convexo-concave surface or is constituted of a porous material member, on the focus electrode and/or on the second insulating layer between one focus electrode and another focus electrode which are adjacent to each other, and (2) the step of forming a gas-trapping layer which is in conformity with the surface of the supporting member, on the supporting member. Except for a case where the getter is formed on the entire surface, the supporting member and the gas-trapping layer may be patterned to complete the getter after the step (2).

[0047] In another specific constitution of the method of producing a flat-panel display, provided by the present invention, the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and the first panel can be produced by the steps of:

(a) forming an insulating layer on a supporting substrate,
(b) forming a gate electrode which is at least partly composed of a gas-trapping material and works as the getter, on the insulating layer,
(c) forming an opening portion at least in the insulating layer, and
(d) forming or exposing an electron-emitting portion in the opening portion.

[0048] The method of producing a flat-panel display, having the above constitution, will be referred to as the production method according to a fifth constitution of the present invention. The flat-panel display according to the third constitution of the present invention can be produced by the production method according to the fifth constitution of the present invention.

[0049] In the production method according to the fifth constitution of the present invention, the gate electrode may have a single-layered structure composed of a gas-trapping material, or the gate electrode may have a stacked structure constituted, at least, of a first layer composed of an electrically conductive material or an electrically insulating material

and a second layer composed of a gas-trapping material.

[0050] In another specific constitution of the method of producing a flat-panel display, provided by the present invention, the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and the first panel can be produced by the steps of;

(a) forming an insulating layer on a supporting substrate,
(b) forming a gate electrode on the insulating layer,
(c) forming a second insulating layer on the insulating layer and the gate electrode,
(d) forming a focus electrode which is at least partly composed of a gas-trapping material and works as the getter, on the second insulating layer,
(e) forming an opening portion at least in the second insulating layer and in the insulating layer, and
(f) forming or exposing an electron-emitting portion in the opening portion.

[0051] The method of producing a flat-panel display, having the above constitution, will be referred to as the production method according to a sixth constitution of the present invention. The flat-panel display according to the fourth constitution of the present invention can be produced by the production method according to the sixth constitution of the present invention.

[0052] In the production method according to the sixth constitution of the present invention, the focus electrode may have a single-layered structure composed of a gas-trapping material, or the focus electrode may have a stacked structure constituted, at least, of a first layer composed of an electrically conductive material or an electrically insulating material and a second layer composed of a gas-trapping material.

[0053] In another specific constitution of the method of producing a flat-panel display, provided by the present invention, the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and the first panel can be produced by the steps of;

(a) disposing a spacer composed of an electrically insulating material on a supporting substrate and forming an electron-emitting portion on the supporting substrate, and
(b) fixing a gate electrode constituted of a gas-trapping material layer which has a plurality of opening portions formed therein and is at least partly composed of a gas-trapping material, such that the gate electrode comes in contact with the top surface of the spacer and that the opening portion is positioned above the electron-emitting portion.

[0054] The method of producing a flat-panel display, having the above constitution, will be referred to as the production method according to a seventh constitution of the present invention. The flat-panel display according to the third constitution of the present invention can be produced by the production method according to the seventh constitution of the present invention.

[0055] In the flat-panel display according to the first constitution of the present invention and the production method according to the third constitution of the present invention, when the getter is formed on the gate electrode, the getter may have the same pattern as that of the gate electrode, or the getter may have a pattern covering the gate electrode. When the getter is formed on the gate electrode, the supporting member and the gas-trapping layer may be composed of either one of an electrically conductive material or an electrically insulating material. When the getter is formed on the insulating layer between the adjacent gate electrodes, the getter may be in contact with side surfaces of the gate electrodes, or the getter may be spaced from the side surfaces of the gate electrodes. However, when the getter is in contact with the side surfaces of the gate electrodes, it is required to select materials for the supporting member and the gas-trapping layer for preventing the short-circuiting between the adjacent gate electrodes with the getter. It is not necessarily required to provide the getters on the insulating layer between all of the adjacent gate electrodes. When the getter is formed on the gate electrode and on the insulating layer between one gate electrode and another gate electrode which are adjacent to each other, the effective area of the getter (area which contributes to trapping the released gas) can be secured to the largest extent. That is, as far as that portion of the supporting member which is in contact with the gate electrode is composed of an electrically insulating material, the getter can be formed nearly on the entire surface excluding the opening portions even if the gas-trapping layer is composed of an electrically conductive material.

[0056] In the flat-panel display according to the second constitution of the present invention and the production method according to the fourth constitution of the present invention, when the getter is formed on the focus electrode, the getter may have the same pattern as that of the focus electrode, or the getter may have a pattern covering the focus electrode. When the getter is formed on the focus electrode, the supporting member and the gas-trapping layer may be composed of either one of an electrically conductive material or an electrically insulating material. When the getter is formed on the second insulating layer between the adjacent focus electrodes, the getter may be in contact

with side surfaces of the focus electrodes, or the getter may be spaced from the side surfaces of the focus electrodes. However, when the getter is in contact with the side surfaces of the focus electrodes, it is required to select materials for the supporting member and the gas-trapping layer for preventing the short-circuiting between the adjacent focus electrodes with the getter. It is not necessarily required to provide the getter on the second insulating layer between all of the adjacent gate electrodes. When the getter is formed on the focus electrode and on the insulating layer between one focus electrode and another focus electrode which are adjacent to each other, the area of the getter can be secured to the largest extent. That is, as far as that portion of the supporting member which is in contact with the focus electrode is composed of an electrically insulating material, the getter can be formed nearly on the entire surface excluding the opening portions even if the gas-trapping layer is composed of an electrically conductive material.

[0057] In the flat-panel displays according to the first and second constitutions of the present invention and the production methods according to the first to fourth constitutions of the present invention, the getters may be provided to the pixels such that one getter corresponds to one pixel, or the getters may be provided such that one getter corresponds to a predetermined number of pixels. When the getters are provided such that one getter corresponds to one pixel, the getter may be provided so as to cover the entire area of the effective field. When the getters are provided such that one getter corresponds to a predetermined number of pixels, the layout of the getters in the effective field may be regular or at random. Further, in the flat-panel displays according to the first and second constitutions of the present invention and the production methods according to the first to fourth constitutions of the present invention, the getters may be provided such that one getter corresponds to one cold cathode field emission device (to be referred to as "field emission device" hereinafter), or the getters may be provided such that one getter corresponds to a predetermined number of the field emission devices. When the getters are provided such that one getter corresponds to one field emission device, the getter may be provided so as to cover the entire area of the effective field. When the getters are provided such that one getter corresponds to a predetermined number of the field emission devices the layout of the getters in the effective field may be regular or at random. In any case, preferably, the effective area of the getters is as large as possible, and the layout thereof has higher regularity, for preventing the released gas from causing a local increase pressure in the vacuum layer. In the flat-panel display of the present invention and the flat-panel displays according to the first and second constitutions of the present invention, the gettering efficiency is remarkably improved as compared with any conventional flat-panel display having the getter provided in one place in the non-effective field, so that the flat-panel displays are remarkably improved in lifetime and image quality.

[0058] The flat-panel display according to any one of the first to fifth constitutions of the present invention can have any type of known cold cathode field emission devices depending upon the layout mode of the electron-emitting portion in the opening portion. For example, there is employed a constitution in which a cathode electrode is formed on the supporting substrate; the insulating layer is formed on the cathode electrode and the supporting substrate; and the electron-emitting portion is formed on the cathode electrode positioned in the bottom portion of the opening portion. The cold cathode field emission device having the above electron-emitting portion on the cathode electrode includes a so-called Spindt-type field emission device having a conical electron-emitting portion, a so-called crown-type field emission device having a crown electron-emitting portion and a so-called flat-type field emission device having a flat electron-emitting portion. Otherwise, there may be employed a constitution in which an electron-emitting layer is formed on the supporting substrate; the insulating layer is formed on the electron-emitting layer and the supporting substrate; and the electron-emitting layer positioned in the bottom portion of the opening portion corresponds to the electron-emitting portion (so-called plane-type field emission device or crater-type field emission device).

[0059] When the flat-panel display having the above Spindt-type field emission devices, crown-type field emission devices or flat-type field emission devices as cold cathode field emission devices is produced by the production method according to any one of the first to sixth constitutions of the present invention, a cathode electrode is formed on the supporting substrate and then the insulating layer is formed on the cathode electrode and the supporting substrate in the step (a) of the production method according to each constitution; and the electron-emitting portion can be formed on the cathode electrode positioned in the bottom portion of the opening portion in the step (f) of the production method according to first constitution, in the step (h) of the production method according to second constitution, in the step (e) of the production method according to third constitution, in the step (g) of the production method according to fourth constitution, in the step (d) of the production method according to fifth constitution, or in the step (f) of the production method according to sixth constitution. The step (f) of the production method according to first constitution, the step (h) of the production method according to second constitution, the step (e) of the production method according to third constitution, the step (g) of the production method according to fourth constitution, the step (d) of the production method according to fifth constitution and the step (f) of the production method according to sixth constitution will be sometimes referred to as the step of forming the electron-emitting portion. Further, when the flat-panel display having the plane-type field emission devices as cold cathode field emission devices is produced by the production method according to any one of the first to sixth constitutions of the present invention, an electron-emitting layer is formed on the supporting substrate and then the insulating layer is formed on the electron-emitting layer and the supporting substrate in the step (a) of the production method according to each constitution; and the electron-emitting layer positioned in the bottom portion

portion of the opening portion can be exposed to expose the electron-emitting portion in the opening portion in the step of forming the electron-emitting portion in the production method according to each constitution.

[0060] Otherwise, in the flat-panel display according to any one of the first to fifth constitution of the present invention, there may be employed a constitution in which the insulating layer covers an electron-emitting layer; the opening portion penetrates through the electron-emitting layer; and an edge portion of the electron-emitting layer exposed on a side wall surface of the opening portion corresponds to the electron-emitting portion. The cold cathode field emission device having an electron-emitting portion formed by exposing the edge portion of the electron-emitting layer on the side wall surface of the opening portion includes a so-called edge-type field emission device.

[0061] When the flat-panel display having the edge-type field emission devices as cold cathode field emission devices is produced by the production method according to any one of the first to sixth constitutions of the present invention, the insulating layer covering an electron-emitting layer is formed in the step (a) of the production method according to each constitution, and an edge portion of the electron-emitting layer is exposed on a side wall surface of the opening portion in the step of forming the electron-emitting portion in the production method according to each constitution.

[0062] The above "insulating layer covering the electron-emitting layer" includes a constitution in which the upper surface and the side surfaces of the electron-emitting layer are covered with the insulating layer and a constitution in which the entirety (i.e., upper surface, side surfaces and bottom surface) of the electron-emitting layer is covered with the insulating layer. In an actual constitution in which the entire circumference of the electron-emitting layer is covered, there can be employed a two-layered structure constituted of an upper insulating layer and a lower insulating layer. For example, after the lower insulating layer is formed, the electron-emitting layer is formed on the lower insulating layer, and then, the upper insulating layer is formed on the electron-emitting layer and the lower insulating layer. When the insulating layer covers only the upper surface and the side surfaces of the electron-emitting layer, the edge portion of the electron-emitting layer is exposed on a lower side of the side wall surface of the opening portion by forming the opening portion in the insulating layer and the electron-emitting layer in the step (e) of the production method according to first constitution, the step (g) of the production method according to second constitution, the step (d) of the production method according to third constitution, the step (f) of the production method according to fourth constitution, the step (d) of the production method according to fifth constitution or the step (f) of the production method according to sixth constitution. The step (e) of the production method according to first constitution, the step (g) of the production method according to second constitution, the step (d) of the production method according to third constitution, the step (f) of the production method according to fourth constitution, the step (d) of the production method according to fifth constitution and the step (f) of the production method according to sixth constitution will be sometimes referred to as "the step of forming the opening portion". When the insulating layer covers the entirety of the electron-emitting layer, the edge portion of the electron-emitting layer can be exposed on the lower side of side wall surface of the opening portion depending upon the depth of the opening portion by forming the opening portion in the insulating layer in the step of forming the opening portion. When a deeper opening portion is formed, the edge portion of the electron-emitting layer can be exposed on that side wall surface of the opening portion which is somewhere in the depth direction of the opening portion. When the insulating layer is formed to have a two-layered structure constituted of the upper and lower insulating layers, there may be also employed a constitution in which a lower gate electrode is pre-formed under the lower insulating layer and an opening portion having the lower gate electrode exposed in the bottom portion thereof can be formed in the insulating layer.

[0063] In the step (e) of the production method according to the first constitution, the step (d) of the production method according to the third constitution and the step (c) of the production method according to the fifth constitution, it is specified that the opening portion is formed "at least" in the insulating layer. The reason for using the above expression is as follows. In some cases, some through holes are formed in the getters and/or the gate electrodes (and further, the electron-emitting layer when the edge-type field emission devices are formed) in a step prior to the above steps, and in such cases, it is sufficient to form the opening portion only in the insulating layer inside such a through hole. In the step (g) of the production method according to the second constitution, the step (t) of the production method according to the fourth constitution and the step (e) of the production method according to the sixth constitution, it is specified that the opening portion is formed "at least" in the second insulating layer and in the insulating layer. The reason for using the above expression is as follows. In some cases, some through holes are formed in the getters, the focus electrodes and/or the gate electrodes (and further, the electron-emitting layer when the edge-type field emission devices are formed) in a step prior to the above steps, and in such cases, it is sufficient to form the opening portion only in the second insulating layer and in the insulating layer inside such a through hole. As a typical method of forming the opening portion in the insulating layer and the second insulating layer, there can be used an etching method using a mask pattern.

[0064] In the getter of the present invention, the flat-panel display of the present invention, the flat-panel displays according to the first and second constitutions of the present invention, the method of producing a flat-panel display, provided by the present invention, and the production methods according to the first to fourth constitutions of the present invention, the supporting member having a convexo-concave (or rough, uneven or irregular) surface may be consti-

tuted, for example, of nearly hemispherical silicon particles. For forming the nearly hemispherical silicon particles, for example, there can be applied a method of growing nearly hemispherical silicon particles for increasing a surface area of a capacitor lower electrode (storage node electrode) in the production of DRAM (random access memory). The formation of the nearly hemispherical silicon particles is generally carried out according to a two-stage process including a seeding stage and a seed-growing stage. In the seeding stage, generally, silicon seeds (nuclei) are formed by a reduced pressure CVD method using a silicon-containing gas. The silicon seeds are formed on the electrically conductive material layer for a gate electrode in the production method according to the first constitution of the present invention, on the electrically conductive material layer for a focus electrode in the production method according to the second constitution of the present invention, on the gate electrode and/or the insulating layer between one gate electrode and another gate electrode which are adjacent to each other in the production method according to the third constitution of the present invention, and on the focus electrode and/or the second insulating layer between one focus electrode and another focus electrode which are adjacent to each other in the production method according to the fourth constitution of the present invention, i.e., on the substratum. In the seed-growing stage to follow, annealing is carried out for adhering silicon atoms to the silicon seeds and growing the seeds to the nearly hemispherical silicon particles.

[0065] In the getter of the present invention, the flat-panel display of the present invention, the flat-panel displays according to the first and second constitutions of the present invention, the method of producing a flat-panel display, provided by the present invention, and the production methods according to the first to fourth constitutions of the present invention, the supporting member constituted of the nearly hemispherical silicon particles may further comprise an amorphous silicon layer formed below the nearly hemispherical silicon particles (i.e., on a side opposite to the side where the gas-trapping layer is to be formed). In the method of producing a flat-panel display according to the present invention, the above supporting member can be obtained by forming an amorphous silicon layer beforehand in portions where the above silicon seeds are to be formed, prior to the formation of the nearly hemispherical silicon particles. The amorphous silicon layer can be formed, for example, by a reduced pressure CVD method. In the surface of the amorphous silicon layer, S-H bonds formed by terminating dangling bonds (unsaturated bonds) of silicon (Si) atoms with hydrogen (H) atoms are present, and the hydrogen atoms in the Si-H bonds are replaced with Si atoms, which results in easy formation of the silicon seeds.

[0066] In the getter of the present invention, the flat-panel display of the present invention, the flat-panel displays according to the first and second constitutions of the present invention, the method of producing a flat-panel display, provided by the present invention, and the production methods according to the first to fourth constitutions of the present invention, the supporting member may be constituted of a porous material member. The supporting member constituted of a porous material member can consist of or formed from at least one material selected from the group consisting of silicon oxide, silicon nitride and silicon oxide nitride (SiON). The silicon oxide includes a so-called xerogel having a low dielectric constant and silicon oxide containing at least one element selected from the group consisting of phosphorus (P), boron (B) and arsenic (As) (for example, BPSG, PSG, BSG, AsSG and PbSG).

[0067] In the method of producing a flat-panel display, provided by the present invention, and the production methods according to the first to fourth constitutions of the present invention, the supporting member constituted of a porous material member can be formed by a process including the step of forming a supporting-member-forming film having a pyrolyzable group (group which causes a pyrolysis under heat) or containing a solvent and the step of heat-treating the supporting-member-forming film to pyrolyze the pyrolyzable group or to volatilize the solvent. For example, a liquid composition prepared by dispersing a material for the supporting member in a solvent is applied onto the substratum (the gate electrode and/or the insulating layer between one gate electrode and another gate electrode which are adjacent to each other, or the focus electrode and/or the second insulating layer between one focus electrode and another focus electrode which are adjacent to each other) to form the supporting-member-forming film, and the supporting-member-forming film is heat-treated to volatilize the solvent contained in the supporting-member-forming film, whereby pores can be formed. Otherwise, the supporting member is formed from a siloxane compound having a pyrolyzable group such as methyl group. In this case, the pyrolyzable group is decomposed by heat treatment, and as a result, pores can be formed.

[0068] In the method of producing a flat-panel display, provided by the present invention, and the production methods according to the first to fourth constitutions of the present invention, the supporting member constituted of a porous material member can be formed by a process including the step of forming a supporting-member-forming film containing a plurality of components having different etching rates, the step of heat-treating the supporting-member-forming film to allow a plurality of the components to undergo phase separation, and the step of removing the component having a relatively higher etching rate by etching. While it is sufficient to use two components having different etching rates for practical purpose, three or more components may be used. When the number of the components is 3 or more, the number of phases caused by the phase separation is not necessarily required to be the number of the components, and it is sufficient to generate at least two phases. Specifically, for example, a borosilicate glass composition containing silicon oxide (SiO_2) and boron oxide (B_2O_3) in an amount more than the solid solubility limit thereof in silicon oxide is

used to form the supporting-member-forming film, the boron oxide is aggregated (phase-separated) by heat treatment, and the aggregated boron oxide is etched with hot water, whereby pores can be formed in sites where boron oxide has formed aggregates.

[0069] Otherwise, in the method of producing a flat-panel display, provided by the present invention, and the production methods according to the first to fourth constitutions of the present invention, the supporting member constituted of a porous material member can be formed by a process including the step of forming a supporting-member-forming film containing a plurality of components having different etching rates and the step of removing the component having a relatively higher etching rate by etching. While it is sufficient to use two components having different etching rates for practical purpose, three or more components may be used. Specifically, for example, two silane derivatives having different organic side chains are used to form the supporting-member-forming film, the supporting-member-forming film is glassified by heat treatment, and the glassified supporting-member-forming film is etched with a diluted hydrofluoric acid aqueous solution. In this case, those portions of the supporting-member-forming film which have a relatively higher solubility based on the organic side chain are dissolved earlier, whereby pores can be formed.

[0070] In the flat-panel displays according to the third to fifth constitutions of the present invention or the production methods thereof (production methods according to the fifth to seventh constitutions of the present invention), the gate electrode or the focus electrode may have a single-layered structure composed of a gas-trapping material or may have a stacked structure constituted, at least, of a first layer composed of an electrically conductive material or an electrically insulating material and a second layer composed of a gas-trapping material (gas-trapping layer). In the latter case, more preferably, the gate electrode or the focus electrode may have a stacked structure constituted, at least, of a first layer composed of an electrically conductive material and a second layer composed of a gas-trapping material (gas gas-trapping layer) or a stacked structure constituted, at least, of a first layer composed of an electrically insulating layer and a second layer composed of an electrically conductive gas-trapping material (gas-trapping layer). In some cases, the gate electrode or the focus electrode may have a stacked structure constituted of a first layer composed of an electrically conductive material, a second layer composed of an electrically insulating material and a third layer composed of a gas-trapping material (gas-trapping layer) or a stacked structure constituted of a first layer composed of an electrically conductive gas-trapping material (gas-trapping layer), a second layer composed of an electrically insulating material and a third layer composed of an electrically conductive gas-trapping material (gas-trapping layer). Further, the gate electrode or the focus electrode may have a stacked structure of four layers or more. When the gate electrode or the focus electrode is formed as that having a stacked structure, not all the portions of the gate electrode or the focus electrode are required to have a stacked structure, and the gate electrode or the focus electrode may partly have a stacked structure. In this case, the non-stacked portion of the gate electrode or the focus electrode is required to have electric conductivity. When the gate electrode or the focus electrode has a stacked structure, for example, of two layers, the first layer and the second layer may have the same patterns, the second layer may have a pattern covering the first layer, or the first layer may have a pattern covering the second layer. When the first layer is composed of an electrically conductive material, the second layer may be composed of any one of an electrically conductive material and an electrically insulating material. When viewed from the supporting substrate, the first layer and the second layer may be stacked in the order of the first layer and the second layer or in the order of the second layer and the first layer. When a stacked structure of three layers is employed, the first layer, the second layer and the third layer may be stacked in the order of the first layer, the second layer and the third layer or in the order of the third layer, second layer and the first layer, when viewed from the supporting substrate. Preferably, the outermost surface is formed of a layer composed of a gas-trapping material in view of an increase in gas-trapping capability.

[0071] In the present invention, the material for the gas-trapping layer or the gas-trapping material or the gas-trapping material layer (these will be sometimes generically referred to as "gas-trapping material") can be selected from materials which are already known as materials for getters. Materials for getters are classified into so-called volatilizable materials which volatilize in a vacuum layer and form a thin film on the surface of an internal device member to exhibit a gettering function such as barium and so-called non-volatilizable materials which maintain a solid state in a vacuum layer and exhibit a gettering function, such as zirconium (Zr), titanium (Ti), zirconium-aluminum alloy, zirconium-vanadium-aluminum alloy, zirconium-vanadium-iron alloy, a titanium-zirconium-vanadium-iron alloy, a mixture of a zirconium powder with a graphite powder, and magnesium. The present invention uses the non-volatilizable materials. Since the gas-trapping layer is required to be in conformity with the surface of the supporting member and is required to be formed on the supporting member, it is preferred to form the gas-trapping layer by a method excellent in step coverage, and it is also preferred to form the gas-trapping layer having such a thickness that the convexo-concave form or pores of the supporting member surface is or are not completely occluded. The method of forming the gas-trapping layer includes a deposition method, a sputtering method and a CVD method. @In the flat-panel display according to the third or fourth constitution of the present invention or the production methods thereof, the gate electrode or the focus electrode having a single-layered structure composed of a gas-trapping material can be also formed by a deposition method, a sputtering method or a CVD method. In the flat-panel display according to the fifth constitution of the present invention or the production method thereof, the gate electrode having a single-layered structure composed of a gas-trapping material

can be formed from the above material having the form of a band or a sheet. In the flat-panel display according to the third or fourth constitution of the present invention or the production methods thereof, when the gate electrode or the focus electrode has a stacked structure constituted, at least, of a first layer composed of an electrically conductive material or an electrically insulating material and a second layer composed of a gas-trapping material, the first layer and the second layer can be formed by a deposition method, a sputtering method, a CVD method or a printing method depending upon each material. When the gate electrode or the focus electrode has at least a two-layered structure, all portions of the gate electrode or the focus electrode may be formed to have a two-layered structure, or all portions of the gate electrode or the focus electrode may be constituted of a first layer and some portions thereof may be constituted of the first layer and a second layer to have a two-layered structure. Otherwise, all portions of the gate electrode or the focus electrode may be constituted of a second layer and some portions thereof may be constituted of a first layer and the second layer to have a two-layered structure. In the flat-panel display according to the fifth constitution of the present invention or the production method thereof, when the gate electrode or the focus electrode is constituted, at least, of a gas-trapping layer having a stacked structure of a first layer composed of an electrically conductive material or an electrically insulating material and a second layer composed of a gas-trapping material, the first layer can be constituted of a metal layer having the form of a band or a sheet and the second layer can be formed on the first layer by a deposition method, a sputtering method, a CVD method, a printing method or an application method, although the method of forming these layers shall not be limited thereto. When the gas-trapping material layer is formed to have a two-layered structure, all portions of the gas-trapping layer may have a two-layered structure, or all portions of the gas-trapping layer may be constituted of a first layer and some portions thereof may be constituted of the first layer and a second layer to have a two-layered structure. Otherwise, all portions of the gas-trapping layer are constituted of a second layer and some portions thereof may be constituted of a first layer and the second layer to form a two-layered structure.

[0072] Preferably, the gas-trapping material has the property of increasing its gas trapping capability with an increase in temperature. The temperature of such a gas-trapping material is increased when the released gas from the fluorescent layer and the like collides with the getter and the gate electrode or the focus electrode, and as a result, such a gas-trapping material is improved in the gas-trapping capability unlike any other ordinary substance which releases gas and the like. There can be therefore overcome unstable performances caused on the flat-panel display by an increase in temperature. Otherwise, the gas-trapping material is preferably a material activated by heat treatment so as to have the gas-trapping capability. The heat treatment includes irradiation of the gas-trapping material with electron beams and heat treatment in a high-temperature furnace having a vacuum atmosphere or an atmosphere of an inert gas such as argon or helium. Otherwise, the gas-trapping material preferably has the property of increasing its gas-trapping capability with an increase in temperature caused by collision of electrons. The temperature of such a gas-trapping material is increased when electrons collide with the getter and the gate electrode or the focus electrode, and as a result, the gas-trapping material is improved in gas-trapping capability unlike any other usual substance which releases gas and the like. There can be therefore overcome unstable performances caused on the flat-panel display by an increase in temperature. Examples of the gas-trapping material having the property of its gas-trapping capability with an increase in temperature includes a zirconium-aluminum alloy and a titanium-zirconium-vanadium-iron alloy.

[0073] In the Spindt-type field emission device, the electron-emitting portion can be composed of at least one material which is selected from the group consisting of metals such as tungsten (W), molybdenum (Mo), titanium (Ti), niobium (Nb), tantalum (Ta), chromium (Cr), aluminum (Al) and copper (Cu); alloys and compounds of these metals (for example, nitrides such as TiN and silicides such as WSi_2, $MoSi_2$, $TiSi_2$ and $TaSi_2$); and silicon (polysilicon or amorphous silicon) containing an impurity. The electron-emitting portions in the Spindt-type field emission device can be formed, for example, by a deposition method, a sputtering method or a CVD method.

[0074] In the crown-type field emission device, the material for the electron-emitting portion includes electrically conductive particles and a combination of electrically conductive particles with a binder. The material of the electrically conductive particles includes carbon-containing materials such as graphite; refractory metals such as tungsten (W), niobium (Nb), tantalum (Ta), titanium (Ti), molybdenum (Mo) and chromium (Cr); and transparent electrically conductive materials such as ITO (indium tin oxide). The binder includes glass such as water glass and general purpose resins. Examples of the general purpose resins include thermoplastic resins such as a vinyl chloride resin, a polyolefin resin, a polyamide resin, a cellulose ester resin and a fluorine resin, and thermosetting resins such as an epoxy resin, an acrylic resin and a polyester resin. For improving electron emission efficiency, preferably, the particle size of the electrically conductive particles is sufficiently small as compared with dimensions of the electron-emitting portion. Although not specially limited, the form of the electrically conductive particles is spherical, polyhedral, plate-like, acicular, columnar or amorphous. Preferably, the electrically conductive particles have such a form that exposed portions formed by the particles form acute projections. Electrically conductive particles having different dimensions and different forms may be used as a mixture. The electron-emitting portion of the crown-type field emission device can be formed, for example, by an application method combined with a lift-off method, a deposition method or a sputtering method.

[0075] In the flat-type field emission device, preferably, the electron-emitting portion is composed of a material having

a smaller work function (than a material for the cathode electrode. The material for the electron-emitting portion can be selected on the basis of the work function of a material for the cathode electrode, a potential difference between the gate electrode and the cathode electrode, a required current density of emitted electrons, and the like. Typical examples of the material for the cathode electrode of the field emission device include tungsten (ϕ = 4.55 eV), niobium (ϕ = 4.02-4.87 eV), molybdenum (ϕ = 4.53 - 4.95 eV), aluminum (ϕ = 4.28 eV), copper (ϕ = 4.6 eV), tantalum (ϕ = 4.3 eV), chromium (ϕ = 4.5 eV) and silicon (ϕ = 4.9 eV). The material for electron-emitting portion preferably has a smaller work function (than these materials, and the value of the work function thereof is preferably approximately 3 eV or smaller. Examples of such a material include carbon (ϕ < 1 eV), cesium (ϕ = 2.14 eV), LaB_6 (ϕ = 2.66 - 2.76 eV), BaO (ϕ = 1.6 - 2.7 eV), SrO (ϕ = 1.25 - 1.6 eV), Y_2O_3 (ϕ = 2.0 eV), CaO (ϕ = 1.6 - 1.86 eV), BaS (ϕ = 2.05 eV), TiN (ϕ = 2.92 eV) and ZrN (ϕ = 2.92 eV). More preferably, the electron-emitting portion is composed of a material having a work function (equal to, or smaller than, 2 eV. The material for the electron-emitting portion is not necessarily required to have electric conductivity.

[0076] As a material for the electron-emitting portion of the flat-type field emission device, particularly, carbon is preferred. More specifically, diamond is preferred, and above all, amorphous diamond is preferred. When the electron-emitting portion is composed of amorphous diamond, an emitted electron current density necessary for a flat-panel display can be obtained at an electric field intensity of 5 x 10^7 V/m or lower. Further, since amorphous diamond is an electric resister, emitted electron currents obtained from the electron-emitting portions can be brought into uniform currents, and the fluctuation of brightness can be suppressed when such field emission devices are incorporated into a tlat-panel display. Further, since the amorphous diamond exhibit remarkably high durability against sputtering by ions of residual gas in the flat-panel display, field emission devices having a longer lifetime can be attained.

[0077] Otherwise, the material for the electron-emitting portion of the flat-type field emission device can be selected from materials which have a secondary electron gain δ greater than the secondary electron gain δ which the electrically conductive material for the cathode electrode has. That is, the above material can be properly selected from metals such as silver (Ag), aluminum (Al), gold (Au), cobalt (Co), copper (Cu), molybdenum (Mo), niobium (Nb), nickel (Ni), platinum (Pt), tantalum (Ta), tungsten (W) and zirconium (Zr); semiconductors such as silicon (Si) and germanium (Ge); inorganic simple substances such as carbon and diamond; and compounds such as aluminum oxide (Al_2O_3), barium oxide (BaO), beryllium oxide (BeO), calcium oxide (CaO), magnesium oxide (MgO), tin oxide (SnO_2), barium fluoride (BaF_2) and calcium fluoride (CaF_2). The material for the electron-emitting portion is not necessarily required to have electric conductivity.

[0078] In the plane-type field emission device, the crater-type field emission device or the edge-type field emission device, the material for the cathode electrode or the electron-emitting layer corresponding to the electron-emitting portion can be selected from metals such as tungsten (W), tantalum (Ta), niobium (Nb), titanium (Ti), molybdenum (Mo), chromium (Cr), aluminum (Al), copper (Cu), gold (Au) and silver (Ag); alloys and compounds of these metals (for example, nitrides such as TiN and silicides such as WSi_2, $Mosi_2$, $TiSi_2$ and $Tasi_2$); semiconductors such as diamond: and a thin carbon film. Although not specially limited, the thickness of the above cathode electrode is approximately 0.05 to 0.5 μm, preferably 0.1 to 0.3 μm. The method for forming the cathode electrode includes deposition methods such as an electron beam deposition method and a hot filament deposition method, a sputtering method, a combination of a CVD method or an ion plating method with an etching method, a screen-printing method and a plating method. When a screen-printing method or a plating method is employed, the cathode electrodes in the form of stripes can be directly formed.

[0079] In the flat-type field emission device, the plane-type field emission device, the crater-type field emission device or the edge-type field emission device, the cathode electrode (or an electrically conductive material layer for a cathode electrode) or the electron-emitting portion (or the electron-emitting layer) can be formed from an electrically conductive paste prepared by dispersing electrically conductive fine particles. Examples of the electrically conductive fine particles include a graphite powder; a graphite powder mixed with at least one of metal powders such as a barium oxide powder and a strontium oxide powder; diamond particles or a diamond-like carbon powder containing at least one of nitrogen, phosphorus, boron and triazole; a carbon-nano-tube powder; an (Sr, Ba, Ca)CO_3 powder; and a silicon carbide powder. It is particularly preferred to select a graphite powder as electrically conductive fine particles in view of a decrease in threshold electric field and an improvement in durability of the electron-emitting portion. The electrically conductive fine particles may have the form of spheres or scales, or they may have a fixed or amorphous form. The particle diameter of the electrically conductive fine particles is not critical so long as it is equal to, or less than. the thickness or the pattern width of the cathode electrode or the electron-emitting portion. With a decrease in the above particle diameter, the number of electrons emitted per unit area can be increased. When the above particle diameter is too small, however, the cathode electrode or the electron-emitting portion may deteriorate in electric conductivity. The above particle diameter is therefore preferably in the range of from 0.01 to 4.0 μm. Such electrically conductive fine particles are mixed with a glass component or other proper binder to prepare an electrically conductive paste, a desired pattern of the electrically conductive paste is formed by a screen-printing method and the pattern is calcined or sintered, whereby the cathode electrode which works as an electron-emitting portion or the electron-emitting portion can be

formed. Otherwise, the cathode electrode which works as an electron-emitting portion or the electron-emitting portion can be formed by a combination with a spin coating method and an etching method.

[0080] In the field emission device having the Spindt-type field emission device or the crown-type field emission device, the material for the cathode electrode (or the electrically conductive material layer for a cathode electrode) can be selected from metals such as tungsten (W), niobium (Nb), tantalum (Ta), molybdenum (Mo), chromium (Cr), aluminum (Al) and copper (Cu); alloys and compounds of these metals (for example, nitrides such as TiN and silicides such as WSi_2, $MoSi_2$, $TiSi_2$ and $TaSi_2$); semiconductors such as silicon (Si); and ITO (indium-tin oxide). The method for forming the cathode electrode includes deposition methods such as an electron beam deposition method and a hot filament deposition method, a sputtering method, a combination of a CVD method or an ion plating method with an etching method, a screen-printing method and a plating method. When a screen-printing method or a plating method is employed, the cathode electrodes in the form of stripes can be directly formed.

[0081] In the flat-panel displays according to the first and second constitutions of the present invention, materials for the cathode electrode, the gate electrode, the upper gate electrode, the lower gate electrode and the focus electrode can be selected from metals such as tungsten (W), niobium (Nb), tantalum (Ta), molybdenum (Mo), chromium (Cr), aluminum (Al) and copper (Cu); alloys and compounds of these metals (for example, nitrides such as TiN and silicides such as WSi_2, $MoSi_2$, $TiSi_2$ and $TaSi_2$); semiconductors such as silicon (Si); carbon; and ITO (indium-tin oxide). The materials for the above electrodes may be the same or different among the electrodes. The above electrodes can be formed by a general thin-film-forming method such as a deposition method, a sputtering method, a CVD method, an ion plating method, a printing method or a plating method.

[0082] In the flat-panel display of the present invention and the method of producing a flat-panel display, provided by the present invention, the supporting substrate of the first panel may be any substrate so long as its surface is composed of an electrically insulating material. Examples of the supporting substrate include a glass substrate, a glass substrate having a surface on which an insulating film is formed, a quartz substrate, a quartz substrate having a surface on which an insulating film is formed, and a semiconductor substrate having a surface on which an insulating film is formed. The substrate of the second panel can have the same constitution as that of the supporting substrate.

[0083] The material for the insulating layer, the second insulating layer, the upper insulating layer or the lower insulating layer includes SiO_2, SiN, SiON, SOG (spin on glass) and a glass paste cured product. These materials may be used alone or in combination. The insulating layer, the second insulating layer, the upper insulating layer or the lower insulating layer can be formed by a known method such as a CVD method, an application method, a sputtering method or a printing method.

[0084] In the flat-panel display according to the fifth constitution of the present invention or the production method thereof (the production method according to the seventh aspect of the present invention), the spacer may be formed in a region between one cathode electrode in the form of a stripe and another cathode electrode in the form of a stripe which are adjacent to each other, or when a plurality of the cathode electrodes are taken as one group, the spacer may be formed in a region between one group and another group which are adjacent to each other. In some cases, the spacer may be formed in the vicinity of a boundary of the effective field and the non-effective field. The material for the spacer can be selected from known electrically insulating materials. For example, a material prepared by mixing a glass having a low melting point with a metal oxide such as alumina can be used. The spacer can be formed, for example, by a screen-printing method, a sandblasting method, a dry film method or a photosensitive method. The dry film method refers to a method in which a photosensitive film is laminated on the supporting substrate, the photosensitive film in portions where the spacers are to be formed is removed by exposure and development, an electrically insulating material is filled in openings formed by the removal of the photosensitive film, and calcining or sintering of the electrically insulating material is carried out. The photosensitive film is combusted and removed by the calcining or sintering, and the electrically insulating material which is filled in the openings remains to form the spacers in the form of ribs. The photosensitive method refers to a method in which a photosensitive electrically insulating material for the spacers is formed on the supporting substrate, the photosensitive electrically insulating material is patterned by exposure and development, and then calcining or sintering of the photosensitive electrically insulating material is carried out. Alternatively, the spacer can be also formed by a known method such as a CVD method, an application method, a sputtering method or a printing method depending upon the material used for the above insulating layer.

[0085] The opening portion of the field emission device (form obtained by cutting the opening portion with an imaginary plane in parallel with the surface of the supporting substrate) may have any arbitrary form such as a circle, an ellipse, a rectangular or square form, a polygon, a roundish rectangular or square form or a roundish polygon. The opening portion can be formed, for example, by an isotropic etching method or a combination of anisotropic and isotropic etching methods. In the field emission device, one electron-emitting portion may exist in one opening portion formed in the gate electrode and the insulating layer, or a plurality of electron-emitting portions may exist in one opening portion formed in the gate electrode and the insulating layer. Otherwise, there may be also employed a constitution in which a plurality of opening portions are formed in the gate electrode, one opening portion communicating with such opening portions is formed in the insulating layer and one or more electron-emitting portions exist in the opening portion formed

in the insulating layer.

[0086] In the field emission device, a resistance layer may be formed between the cathode electrode and the electron-emitting portion. Otherwise, when the cathode electrode surface or the edge portion of the cathode electrode corresponds to the electron-emitting portion, that is, when the field emission device is a plane-type field emission device or an edge-type field emission device, the cathode electrode may have a three-layered structure constituted of an electrically conductive material layer, a resistance layer and an electron-emitting layer corresponding to the electron-emitting portion. The resistance layer can stabilize performances of the field emission device and can attain uniform electron-emitting properties. The material for the resistance layer includes carbon-containing materials such as silicon carbide (SiC); SiN; semiconductor materials such as amorphous silicon; and refractory metal oxides such as ruthenium oxide (RuO_2), tantalum oxide and tantalum nitride. The resistor layer can be formed by a sputtering method, a CVD method or a screen-printing method. The resistance value of the resistance layer is approximately 1×10^5 to $1 \times 10^7 \Omega$, preferably several MΩ.

[0087] In the flat-panel displays according to the first to fifth constitutions of the present invention, the getter of the present invention may be provided in the effective field of the second panel.

[0088] When the flat-panel displays according to the first to fifth constitutions of the present invention are applied to cold cathode field emission displays, general constitutions of the second panel include one type constitution in which the anode electrode is formed on the entire surface of the substrate within the effective field and the fluorescent layer having a predetermined form is formed on the anode electrode and other type constitution in which the fluorescent layer having a predetermined pattern is formed on the substrate within the effective field and the anode electrode which also works as a metal backing is formed entirely on the fluorescent layer and the substrate. In the former type, a so-called metal backing layer conducting to the anode electrode may be formed on the fluorescent layer. In the latter type, a metal backing layer may be also formed on the anode electrode. The anode electrode may have a constitution in which the effective field is covered with an electrically conductive material having the form of one sheet form or in which anode electrode units each of which corresponds to one or a plurality of electron-emitting regions are provided as a set. The fluorescent layer is formed in the form of a stripe or dots. In a color display, fluorescent layers which are patterned in the form of stripes or dots and correspond to three primary colors of red (R), green (G) and blue (B) are alternately arranged. The fluorescent layers in the form of stripes or dots are opposed to the electron-emitting regions. A black matrix may be formed between one fluorescent layer and another fluorescent layer which are adjacent to each other. In any one of the flat-panel displays according to the first to fifth constitutions of the present invention, the getter of the present invention may be formed in a portion which is in the effective region having no fluorescent layer formed and which faces the vacuum layer (for example, on the anode electrode). In a practical constitution of the second panel, when a black matrix for improving a contrast is filled in a space between the adjacent fluorescent layers, the getter of the present invention may be provided on the black matrix or the anode electrode positioned on the black matrix. The anode electrode can be constituted, for example, of a metal thin film of aluminum or a transparent electrically conductive material such as ITO (indium tin oxide).

[0089] In the flat-panel display or the production method thereof according to the present invention, the getter is provided near a portion where the released gas is generated, or the gate electrode or the focus electrode works as the getter, so that the gas-trapping function of these can effectively prevent an increase in pressure and discharging in the vacuum layer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0090] The present invention will be explained with reference to drawings hereinafter.

[0091] Figs. 1A, 1B and 1C show schematic constitutions of the getter of the present invention.

[0092] Figs. 2A, 2B and 2C are conceptual views of the flat-panel display of the present invention.

[0093] Figs. 3A, 3B, 3C and 3D are schematic end views for showing constitutions of the cold cathode field emission device as a constituent of a flat-panel display according to the first constitution of the present invention.

[0094] Figs. 4A, 4B and 4C are schematic end views for showing constitutions of the cold cathode field emission device as a constituent of a flat-panel display according to the first constitution of the present invention.

[0095] Figs. 5A and 5B are schematic partial end views of a supporting substrate, etc., for explaining the method of producing a flat-panel display in Example 2.

[0096] Figs. 6A and 6B, following Fig. 5B, are schematic partial end views of the supporting substrate, etc., for explaining the method of producing the flat-panel display in Example 2.

[0097] Figs. 7A and 7B, following Fig. 6B, are schematic partial end views of the supporting substrate, etc., for explaining the method of producing the flat-panel display in Example 2.

[0098] Figs. 8A, 8B, 8C and 8D are schematic partial end views of a substrate, etc., for explaining one example of the method of producing a second panel (anode panel).

[0099] Fig. 9 is a schematic partial cross-sectional view of a flat-panel display (cold cathode field emission display)

in Example 2.

[0100] Fig. 10 is a schematic conceptual perspective view showing a disassembled state of the first panel and the second panel of the flat-panel display of Example 2.

[0101] Fig. 11 is a schematic exploded perspective view of the first panel and the second panel of the flat-panel display of Example 2.

[0102] Figs. 12A and 12B are schematic partial end views of a supporting substrate, etc., for explaining the method of producing a cold cathode field emission device as a constituent for a flat-panel display of Example 6.

[0103] Figs. 13A and 13B, following Fig. 12B, are schematic partial end views of the supporting substrate, etc., for explaining the method of producing the cold cathode field emission device as a constituent for the flat-panel display of Example 6.

[0104] Figs. 14A and 14B are schematic partial end views of the supporting substrate, etc., for explaining the method of producing a cold cathode field emission device as a constituent for the flat-panel display of Example 7.

[0105] Figs. 15A, 15B and 15C are schematic partial end views for showing the formation pattern of a getter in Example 7.

[0106] Figs. 16A and 16B are schematic partial end views of a supporting substrate, etc., for explaining the method of producing a flat-panel display in Example 8.

[0107] Figs. 17A, 17B and 17C are schematic partial end views for showing the formation pattern of a getter in Example 10.

[0108] Figs. 18A and 18B are schematic partial end views of a supporting substrate, etc., for explaining the method of producing a flat-panel display in Example 9.

[0109] Figs. 19A and 19B are schematic partial end views of variants of the electron-emitting portion constituting the flat-panel display of Example 9.

[0110] Figs. 20A, 20B and 20C are schematic partial end views of variants of the electron-emitting portion constituting the flat-panel display of Example 9.

[0111] Figs. 21A, 21B and 21C schematically show examples of pressure distribution of a vacuum layer in the flat-panel display of Example 9.

[0112] Figs. 22A and 22B are schematic partial end views of a supporting substrate, etc., for explaining the method of producing a flat-panel display of Example 10.

[0113] Fig. 23 is a schematic partial cross-sectional view of a supporting substrate, etc., for explaining the method of producing a flat-panel display of Example 11.

[0114] Fig. 24 is a characteristic diagram showing a relationship between the temperature of a zirconium-aluminum alloy and a vacuuming rate in an internal space in a flat-panel display.

[0115] Fig. 25A is a schematic partial cross-sectional view of a supporting substrate, etc., for explaining the method of producing a flat-panel display of Example 12, and Fig. 25B is a schematic layout of the gate electrodes, etc.

[0116] Figs. 26A, 26B, 26C and 26D are schematic plan views of a plurality of opening portions of a gate electrode.

[0117] Figs. 27A and 27B are schematic partial end views of a supporting substrate, etc., for explaining the method of producing a crown-type field emission device in a flat-panel display of Example 13.

[0118] Figs. 28A, 28B and 28C, following Fig. 27B, are schematic partial end views of the supporting substrate, etc., for explaining the method of producing the crown-type field emission device in the flat-panel display of Example 13.

[0119] Fig. 29A following Fig. 28B, is a schematic partial end view of the supporting substrate, etc., and Fig. 29B is a partially cut-out schematic perspective view of the supporting substrate, etc., for explaining the method of producing the crown-type field emission device in the flat-panel display of Example 13.

[0120] Figs. 30A, 30B and 30C are schematic partial cross-sectional views of a supporting substrate, etc., for explaining the method of producing a flat-type field emission device in a flat-panel display of Example 14.

[0121] Figs. 31A 31B and 31C are schematic partial cross-sectional views of a supporting substrate, etc., for explaining the method of producing a flat-type field emission device in a flat-panel display of Example 15.

[0122] Figs. 32A and 32B are schematic partial cross-sectional views of plane-type field emission devices in a flat-panel display of Example 16.

[0123] Fig. 33 is a schematic partial cross-sectional view of a variant of the plane-type field emission device in the flat-panel display of Example 16.

[0124] Figs. 34A and 34B are a schematic partial end view and a partial perspective view of a supporting substrate, etc., respectively, for explaining the

[0125] method of producing a crater-type field emission device in a flat-panel display of Example 17.

[0126] Figs. 35A and 35B, following Figs. 34A and 34B, are a schematic partial end view and a partial perspective view of the supporting substrate, etc., respectively, for explaining the method of producing the crater-type field emission device in the flat-panel display of Example 17.

[0127] Figs. 36A and 36B, following Figs. 35A and 35B, are a schematic partial end view and a partial perspective view of the supporting substrate, etc., respectively, for explaining the method of producing the crater-type field emission

device in the flat-panel display of Example 17.

[0128] Figs. 37A and 37B, following Figs. 36A and 36B, are schematic partial cross-sectional views of the supporting substrate, etc., for explaining the method of producing the crater-type field emission device in the flat-panel display of Example 17.

[0129] Figs. 38A, 38B and 38C are schematic partial cross-sectional views of a supporting substrate, etc., for explaining the method of producing a crater-type field emission device in a flat-panel display of Example 18.

[0130] Figs. 39A, 39B and 39C are schematic partial cross-sectional views of a supporting substrate, etc., for explaining the method of producing a crater-type field emission device in a flat-panel display of Example 19.

[0131] Figs. 40A and 40B are schematic partial end views of a supporting substrate, etc., for explaining the method of producing a crater-type field emission device in a flat-panel display of Example 20.

[0132] Figs. 41A and 41B, following Fig. 40B, are schematic partial end views of the supporting substrate, etc., for explaining the method of producing the crater-type field emission device in the flat-panel display of Example 20.

[0133] Figs. 42A, 42B and 42C are schematic partial cross-sectional views of a supporting substrate, etc., for an edge-type field emission device in a flat-panel display of Example 21.

[0134] Figs. 43A, 43B and 43C are schematic partial end views of the supporting substrate, etc., for explaining the method of producing the edge-type field emission device.

[0135] Figs. 44A and 44B are schematic partial end views of a supporting substrate, etc., for explaining the method of producing a Spindt-type field emission device shown in Fig. 47 in a flat-panel display of Example 22.

[0136] Figs. 45A and 45B, following Fig. 44B, are schematic partial end views of the supporting substrate, etc., for explaining the method of producing the Spindt-type field emission device shown in Fig. 47.

[0137] Figs. 46A and 46B, following Fig. 45B, are schematic partial end views of the supporting substrate, etc., for explaining the method of producing the Spindt-type field emission device shown in Fig. 47.

[0138] Fig. 47 is a schematic partial end view of a Spindt-type field emission device.

[0139] Figs. 48A and 48B show the mechanism of forming a conical electron-emitting portion.

[0140] Figs. 49A, 49B and 49C schematically show relationships of a selective ratio to a resist and the height and form of an electron-emitting portion.

[0141] Figs. 50A and 50B are schematic partial end views of a supporting substrate, etc., for explaining the method of producing a Spindt-type field emission device in a flat-panel display of Example 23.

[0142] Figs. 51A and 51B, following Fig. 50B, are schematic partial end views of the supporting substrate, etc., for explaining the method of producing the Spindt-type field emission device in the flat-panel display of Example 23.

[0143] Figs. 52A and 52B, following Fig. 51B, are schematic partial end views of the supporting substrate, etc., for explaining the method of producing the Spindt-type field emission device in the flat-panel display of Example 23.

[0144] Figs. 53A and 53B show how the surface profile of a material being etched changes per constant time period.

[0145] Figs. 54A and 54B are schematic partial end views of a supporting substrate, etc., for explaining the method of producing a Spindt-type field emission device in a flat-panel display of Example 24.

[0146] Fig. 55 following Fig. 54B is a schematic partial end view of the supporting substrate, etc., for explaining the method of producing the Spindt-type field emission device in the flat-panel display of Example 24.

[0147] Fig. 56 is a schematic partial end view of a Spindt-type field emission device in a flat-panel display of Example 25.

[0148] Figs. 57A and 57B are schematic partial end views of a supporting substrate, etc., for explaining the method of producing a Spindt-type field emission device of Example 25.

[0149] Figs. 58A and 58B, following Fig. 57B, are schematic partial end views of the supporting substrate, etc., for explaining the method of producing the Spindt-type field emission device of Example 25.

[0150] Figs. 59A and 59B, following Fig. 58B, are schematic partial end views of the supporting substrate, etc., for explaining the method of producing the Spindt-type field emission device of Example 25.

[0151] Figs. 60A and 60B are schematic partial end views of a supporting substrate, etc., for explaining the method of producing a Spindt-type field emission device in a flat-panel display of Example 26.

[0152] Figs. 61A and 61B, following Fig. 60B, are schematic partial end views of the supporting substrate, etc., for explaining the method of producing the Spindt-type field emission device of Example 26.

[0153] Fig. 62 is a schematic partial end view of a supporting substrate, etc., for explaining the method of producing a Spindt-type field emission device in a flat-panel display of Example 27.

[0154] Fig. 63 shows one example of a driving circuit of a flat-panel display when all of gate electrodes are constituted of one sheet-like electrode-constituting layer.

[0155] Fig. 64 shows one example of a driving circuit of a flat-panel display when all of cathode electrodes are constituted of one sheet-like electrode-constituting layer.

[0156] Fig. 65 is a schematic partial end view of a flat-panel display in which a focus electrode is provided above a gate electrode through a vacuum layer.

[0157] Fig. 66 is a conceptual exploded view of a conventional flat-panel display.

[0158] Fig. 67 shows a schematic layout of constituting elements in a conventional first panel shown in Fig. 66.
[0159] Fig. 68 schematically shows an example of a pressure distribution in a vacuum layer when gas molecules are released from an electron-emitting portion in a conventional flat-panel display.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Example 1

[0160] Example 1 is concerned with the getter and the flat-panel display of the present invention. The constitution of the getter of the present invention will be explained with reference to Figs. 1A, 1B and 1C. A getter 43A shown in Fig. 1A (to be referred to as "first-type getter 43A") comprises a supporting member 41 which is formed on a substratum 40 and has a convexo-concave surface, and a gas-trapping layer 42 which is formed on the supporting member in conformity with the surface of the supporting member. The supporting member in Example 1 is constituted of hemispherical silicon particles 41 (corresponding to nearly hemispherical silicon particles). Fig. 1B shows a getter 43B (to be referred to as "second-type getter 43B") of which the supporting member is constituted of an amorphous silicon layer 44 formed on the substratum 40 and the hemispherical silicon particles 41 formed on the amorphous silicon layer 44. When it is difficult to grow the supporting member constituted of hemispherical silicon particles directly on the surface of the substratum 40, the amorphous silicon layer 44 serves to ease the formation of silicon seeds (nuclei) to promote the growth of the hemispherical silicon particles 41. In a getter 43C shown in Fig. 1C (to be referred to as "third-type getter 43C"), the supporting member is constituted of a porous material member 45. In any one of the first-type, second type and third-type getters 43A, 43B and 43C, the surface area of the gas-trapping layer 42 increases as compared with a case where the a gas-trapping layer has a flat surface, so that the gas-trapping layer 42 can efficiently traps a released gas present in an outer environment. The first-type, second-type or third-type getter 43A, 43B or 43C of the present invention can be applied to the flat-panel display of the present invention and the flat-panel displays according to the first and second constitutions of the present invention, and the can be also applied to a cathode ray tube.
[0161] Figs. 2A, 2B and 2C show schematic constitution examples of the flat-panel display of the present invention. In the flat-panel display shown in Fig. 2A, a first panel P_1 and a second panel P_2 are opposed to each other through a vacuum layer VAC, effective regions EF_1 and EF_2 having pixels arranged are provided, and a getter for maintaining the vacuum degree of the vacuum layer VAC is provided in the effective region EF_1 of the first panel P_1. The first panel P_1 and the second panel P_2 are bonded to each other through a seal member S in their circumferential portions. In the flat-panel display shown in Fig. 2B, a getter for maintaining the vacuum degree of the vacuum layer VAC is provided in the effective region EF_2 of the second panel P_2. In the flat-panel display shown in Fig. 2C, getters for maintaining the vacuum degree of the vacuum layer VAC are provided in the effective region EF_1 of the first panel P_1 and the effective region EF_2 of the second panel P_2. If the first panel P_1 and the second panel P_2 are the cathode panel and the anode panel of a cold cathode field emission display, respectively, the getter may be provided in the cathode panel, the anode panel or both.
[0162] The seal member S may be an adhesive layer, or it may be a combination of a frame composed of an insulating rigid material such as glass or ceramic with an adhesive layer. When a combination of the frame with the adhesive layer is employed, a long distance between the facing panels can be secured by selecting a proper height of the frame as compared with a case using an adhesive alone. While frit glass is generally used for the adhesive layer, a low-melting metal material having a melting point of 120 to 400 °C may be used. The low-melting metal material includes in (indium, melting point 157 °C); an indium-gold-containing low-melting alloy; tin (Sn)-containing high-temperature solders such as $Sn_{80}Ag_{20}$ (melting point 220 - 370 °C) and $Sn_{95}Cu_5$ (melting point 227 - 370 °C); lead (Pb)-containing high-temperature solders such as $Pb_{97.5}Ag_{2.5}$ (melting point 304 °C), $Pb_{94.5}Ag_{5.5}$ (melting point 304 - 365 °C) and $Pb_{97.5}Ag_{1.5}Sn_{1.0}$ (melting point 309 °C); zinc (Zn)-containing high-temperature solders such as $Zn_{95}A_{15}$ (melting point 380 °C); tin-lead-containing standard solders such as Sn_2Pb_{98} (melting point 316 - 322 °C); and soldering materials such as $Au_{88}Ga_{12}$ (melting point 381 °C). All of the above subscript values show atomic %.
[0163] When the first panel P_1, the second panel P_2 and the frame are bonded, these members may be bonded at the same time, or one of the panels and the frame may bonded in advance at a first step and the other panel may be bonded to the frame at a second step. When these three members are bonded at the same time or the other panel is bonded to the frame at a second step in a vacuum container, a space surrounded by the first panel P_1, the second panel P_2 and the frame comes to be a vacuum layer VAC concurrently with the bonding. Otherwise, a space surrounded by the first panel P_1, the second panel P_2 and the seal member S may be vacuumed to form a vacuum layer VAC after these three members are bonded. When the vacuuming is carried out after the bonding, the atmosphere for the bonding may be at atmospheric pressure or reduced pressure, and it may be atmosphere (an air atmosphere) or an inert gas atmosphere containing nitrogen gas or a gas coming under the group 0 of the periodic table (for example, Ar gas).
[0164] When the vacuuming is carried out after the bonding, the vacuuming can be carried out through a tip tube

(not shown) pre-connected to the first panel P_1 and/or the second panel P_2. Typically, the tip tube is made of a glass tube and is bonded to a circumference of a through hole formed in a non-effective field NE_1 of the first panel P_1 (i.e., an area other than the effective field EF_1 which works as a display portion) and/or to a circumference of a through hole formed in a non-effective field NE_2 of the first panel P_2 (i.e., an area other than the effective field EF_2 which works as a display portion), with a frit glass or the above low-melting metal material. After the space reaches a predetermined vacuum degree, the gas-trapping layer or the gas-trapping material is activated, for example, by heat treatment, and the tip tube is sealed by thermal fusion.

[0165] The flat-panel displays according to the first constitution of the present invention will be explained with reference to Figs. 3A, 3B, 3C and 3D. For simplification, these Figures show only cold cathode field emission devices (to be referred to as "field emission device" hereinafter) and the getter formed in the effective field EF_1 of the first panel P_1. The field emission device comprises a cathode electrode 11 formed on a supporting substrate 10; an insulating layer 12 formed on the cathode electrode 11 and the supporting substrate 10; a gate electrode 13 formed on the insulating layer 12; an opening portion 14 which penetrates through the gate electrode 13 and is formed in the insulating layer 12; and an electron-emitting portion 15, 15A, 15B or 15C provided on the cathode electrode 11 positioned in a bottom portion of the opening portion 14. The first panel P_1 has a getter provided on the gate electrode 13. While the second-type getter 43B is shown in Figures, the first type getter 43A or the third-type getter 43C may be used. The field emission device shown in Fig. 3A is a so-called Spindt-type field emission device and has the conical electron-emitting portion 15. The field emission device shown in Fig. 3B is a crown-type field emission device, and it has a crown-shaped electron-emitting portion 15A. The field emission device shown in Fig. 3C is a flat-type field emission device, and it has a flat electron-emitting portion 15B. The electron-emitting portion 15B is composed of a material having higher electron emission efficiency than general refractory metals, for attaining a sufficient emitted electron current in spite of being flat. Further, the field emission device shown in Fig. 3D is a plane-type field emission device, and an exposed portion of the cathode electrode 11 in the bottom portion of the opening portion 14 corresponds to the electron-emitting portion 15C.

[0166] The other flat-panel displays according to the first constitution of the present invention will be explained with reference to Figs. 4A, 4B and 4C hereinafter. For simplification, Figs. 4A to 4C show only field emission devices (edge-type field emission device) and a getter formed in an effective field EF_1 of a first panel P_1. In these Figures, the field emission device comprises an insulating layer which is formed on a supporting substrate 10 and covers an electron-emitting layer 111; a gate electrode 13 formed on the insulating layer; an opening portion 14 which penetrates through the gate electrode 13 and the electron-emitting layer 111 and is formed in the insulating layer; and an electron-emitting portion constituted of that edge portion 111A of the electron-emitting layer 111 which is exposed on a side wall surface of the opening portion 14. The first panel P_1 further has a getter provided on the gate electrode 13. While Figs. 4A to 4C show the second-type getter 43B, the first-type getter 43A or the second-type getter 43C may be used. In the field emission device shown in Fig. 4A, the insulating layer is a single-layered insulating layer 12, and the electron-emitting layer 111 is formed in contact with the supporting substrate 10. In the field emission device shown in Fig. 4B, the insulating layer comprises a lower insulating layer 12A formed below the electron-emitting layer 111 and an upper insulating layer 12B formed on the electron-emitting layer 111, and the opening portion 14 is not only formed through the upper insulating layer 12B but also formed so as to remove part of the lower insulating layer 12A. In the field emission device shown in Fig. 4C, the insulating layer comprises a lower insulating layer 12A formed below the electron-emitting layer 111 and an upper insulating layer 12B formed on the electron-emitting layer 111, and a first gate electrode 13A is further formed below the lower insulating layer 12A and is exposed in a bottom portion of the opening portion 14. Further, a second gate electrode 13B is formed on the upper insulating layer 12B. The first gate electrode 13A serves to form a higher-intensity electric field near the edge portion 111A of the electron-emitting layer 111. The edge portion 111A corresponds to an electron-emitting portion and is projected through the side wall surface of the opening portion 14. Field emission devices of other types will be discussed later.

Example 2

[0167] Example 2 is concerned with the production method according to the first constitution of the present invention and the flat-panel display according to the first constitution of the present invention obtained by the above production method. Figs. 5A, 5B, 6A, 6B, 7A, 7B and 8A to 8D show steps of the production method of a flat-panel display (cold cathode field emission display) having a Spindt-type field emission device shown in Fig. 3A as a typical example of the flat-panel display according to the first constitution, and Fig. 9 shows a general drawing of the flat-panel display. Fig. 10 shows a schematic exploded conceptual perspective view of the flat-panel display. Fig. 11 shows a schematic exploded perspective view of the flat-panel display.

[0168] In the production method in Example 2, the second-type getter 43B shown in Fig. 1B is used as a specific example. The second-type getter 43B may be replaced with the first-type getter 43A or the third-type getter 43C. For simplification, Figs. 5A, 5B, 6A, 6B, 7A and 7B show only the field emission device and the getter provided in the

effective region of a first panel P_1. In Figs. 6A, 6B, 7A and 7B, further, one opening portion and one electron-emitting portion are shown per gate electrode.

[0169] The method of producing the Spindt-type field emission device is basically a method in which the conical electron-emitting portion 15 is formed by vertical deposition of a metal material. That is, vaporized particles enter perpendicularly to the opening portion 14. The vaporized particles which reach the bottom portion of the opening portion 14 are gradually decreased in amount by utilizing a shielding effect of an overhanging deposit formed in the vicinity of edge portion of the opening portion 14, whereby the electron-emitting portion 15 as a conical deposit is formed in a self-aligned manner. The method of producing a flat-panel display having Spindt-type field emission devices on the basis of a method in which a peel layer 18 is formed on the gate electrode 13 beforehand for making it easy to remove the unnecessary overhanging deposit will be outlined with reference to Figs. 5A, 5B, 6A, 6B, 7A and 7B showing schematic partial end views of the supporting substrate, etc., and Figs. 8A to 8D showing schematic partial cross-sectional views of the substrate, etc., of the second panel P_2 hereinafter.

[Step-200]

[0170] First, an approximately 0.2 μm thick electrically conductive material layer, composed of chromium, for a cathode electrode is formed on the supporting substrate 10 made, for example, of a glass substrate. The electrically conductive material layer is patterned in the form of stripes according to lithography and an etching method, to form the cathode electrode 11. Then, the insulating layer 12 is formed on the cathode electrode 11 and the supporting substrate 10. In this Example, for example, an approximately 1 μm thick SiO_2 layer is formed by a CVD method using TEOS (tetraethoxysilane) as a source gas. Then, an electrically conductive material layer for forming gate electrodes (electrically conductive material layer 13' for a gate electrode) is formed on the insulating layer 12. In this Example, for example, an approximately 0.2 μm thick chromium layer is formed as the electrically conductive material layer 13' by a sputtering method.

[0171] Further, a getter-forming layer 43 is formed on the electrically conductive material layer 13' for a gate electrode. The getter-forming layer 43 comprises, from the bottom, the amorphous silicon layer 44, the hemispherical silicon particles 41 and the gas-trapping layer 42 composed, for example, of an aluminum-zirconium alloy (see Fig. 1B). The amorphous silicon layer 44 and the hemispherical silicon particles 41 constitute the supporting member. Table 1 shows an example of a condition for forming the amorphous silicon layer 44 by a reduced pressure CVD method. PH_3 may not be added. Table 2 shows one example of a condition for forming the seeds by a reduced pressure CVD method in the step of forming the hemispherical silicon particles 41. Further, the gas-trapping layer 42 composed, for example, of an aluminum-zirconium alloy is formed on the supporting member by a sputtering method (see Fig. 5A).

Table 1

[Condition for forming amorphous silicon layer]	
SiH4 flow rate	15 SCCM
PH_3 flow rate	2 SCCM
Pressure	1 x 10^{-3} Pa
Forming temperature	540 °C

Table 2

[Condition for forming seeds]	
SiH_4 flow rate	20 SCCM
He flow rate	30 SCCM
Pressure	1.33 x 10^{-3} Pa
Seeds-Forming temperature	560 °C

[Step-210]

[0172] Then, an etching mask EM is formed on the getter-forming layer 43 by photolithography, and with using the etching mask EM, the getter-forming layer 43 and the electrically conductive material layer 13' for a gate electrode are patterned by reactive ion etching, whereby the gate electrode 13 having the second-type getter 43B formed on its

surface can be formed (see Fig. 5B).

[Step-220]

[0173] Then, the etching mask EM is removed, and a new etching mask EM is formed on the second-type getter 43B and the insulating layer 12. With using the etching mask EM, the second-type getter 43B, the gate electrode 13 and the insulating layer 12 are consecutively etched, to form the opening portion 14 having the cathode electrode 11 exposed in its bottom portion. The opening portion can be formed in the second-type getter 43B and the gate electrode 13 by reactive ion etching, and the opening portion can be formed in the insulating layer 12 by wet etching with a buffered hydrofluoric acid aqueous solution. The etching of the insulating layer 12 isotropically proceeds, so that the side wall surface of the opening portion 14 is allowed to recede behind an end portion of the gate electrode 13 as shown in Fig. 6A. The recess amount in this case can be controlled on the basis of the length of an etching time period. Such a form of the opening portion 14 is advantageous for increasing the electric field intensity in the opening portion 14.

[Step-230]

[0174] Then, the etching mask EM is removed, and aluminum is obliquely deposited on the entire surface, to form a peel layer 18 as shown in Fig. 6B. In this case, a sufficiently large incidence angle of vaporized particles with regard to a normal of the supporting substrate 10 is set, whereby the peel layer 18 can be formed on the second-type getter 43B and the insulating layer 12 almost without depositing aluminum in the bottom portion of the opening portion 14. The peel layer 18 extends from the opening edge portion of the opening portion 14 like eaves, whereby the opening portion 14 is substantially decreased in diameter.

[Step-240]

[0175] Then, for example, molybdenum (Mo) is vertically deposited on the entire surface. In this case, with the growth of an electron-emitting-portion-forming layer 19 having an overhanging form on the peel layer 18, the substantial diameter of the opening portion 14 is gradually decreased, so that vaporized particles which serve to deposition in the bottom portion of the opening portion 14 gradually come to be limited to particles which pass by the center of the opening portion 14. As a result, as shown in Fig. 7A, a conical deposit is formed on the cathode electrode 11 positioned in the bottom portion of the opening portion 14, and the conical deposit constitutes the electron-emitting portion 15.

[Step-250]

[0176] Then, the peel layer 18 is removed together with the electron-emitting-portion-forming layer 19 with a phosphoric acid aqueous solution, whereby a Spindt-type field emission device as shown in Fig. 7B can be completed.

[Step-260]

[0177] The first panel (cathode panel) P_1 having such field emission devices formed in a large number and the second panel (anode panel) P_2 are combined, whereby the flat-panel display can be obtained. Specifically, an approximately 1 mm high frame 24 made, for example, of a ceramic or glass is provided, the frame 24, the first panel P_1 and the second panel P_2 are bonded, for example, with a frit glass, and the frit glass is dried, then followed by calcining or sintering the frit glass at approximately 450 °C for 10 to 30 minutes. Then, the inner space of the flat-panel display is vacuumed until it has a vacuum degree of approximately 10^{-4} Pa, and then the gas-trapping layer (gas-trapping material) is activated, for example, by heat treatment. Then, a tip tube 17 is sealed by a proper method. Otherwise, the frame 24, the first panel P_1 and the second panel P_2 may be bonded in a high-vacuum atmosphere. Otherwise, for some structure of the flat-panel display, the first panel P_1 and the second panel P_2 may be bonded to each other without the frame.

[0178] One example of the method of producing the second panel P, will be explained with reference to Figs. 8A to 8D below. First, a composition of light-emitting crystal particles is prepared. For example, a dispersing agent is dispersed in pure water, and the dispersion is stirred with a homomixer at 3000 rpm for 1 minute. Then, light-emitting crystal particles are poured into the pure water with the dispersing agent, and the mixture is stirred with a homomixer at 5000 rpm for 5 minutes. Then, for example, polyvinyl alcohol and ammonium bichromate are added, and the mixture is fully stirred and filtered.

[0179] In the production of the second panel P_2, a photosensitive film 25 is formed (applied) on the entire surface of the substrate 20 made, for example, of a glass. The photosensitive film 25 is exposed to light which comes from a light source (not shown) and passes through an opening 29 formed in a mask 28, to form an exposed region 26 (see Fig.

8A). Then, the photosensitive film 25 is selectively removed by development, to retain a remaining portion 27 of the photosensitive film (exposed and developed photosensitive film) on the substrate 20 (see Fig. 8B). Then, a carbon agent (carbon slurry) is applied onto the entire surface, and the applied carbon agent is dried and calcined or sintered. Then, the remaining portion 27 of the photosensitive film and the carbon agent thereon are removed by a lift-off method, to form a black matrix 22 composed of the carbon agent on the exposed substrate 20 (see Fig. 8C). Then, red, green and blue fluorescent layers 21 are formed on the exposed substrate 20 (see Fig. 8D). Specifically, compositions of light-emitting crystal particles are prepared from the light-emitting crystal particles (fluorescent particles). For example, a photosensitive composition of red light-emitting crystal particles (fluorescent material slurry) is applied onto the entire surface, followed by exposure and development. A photosensitive composition of green light-emitting crystal particles (fluorescent material slurry) is applied onto the entire surface, followed by exposure and development. Further, a photosensitive composition of blue light-emitting crystal particles (fluorescent material slurry) is applied onto the entire surface, followed by exposure and development. Then, an anode electrode 23 is formed on the fluorescent layers 21 and the black matrix 22 by a sputtering method. The anode electrode 23 is constituted of an aluminum thin film having a thickness of approximately 0.07 μm. Alternatively, each fluorescent layer 21 can be formed by a screen-printing method or the like.

[0180] Fig. 9 shows a constitution example of the flat-panel display of Example 2. While Fig. 9 shows one opening portion 14 and two electron-emitting portions 15 per one line of the gate electrode 13, the basic constitution of the Spindt-type field emission device is as shown in Fig. 7B. The above Spindt-type field emission devices are formed in the effective field EF_1 of the first panel P_1 (also called a cathode panel). The second panel P_2 (also called an anode panel) comprises the substrate 20, the fluorescent layers 21 (fluorescent layers 21R, 21G, 21B) formed on the substrate 20 according to predetermined patterns and the anode electrode 23 formed on the entire surfaces of the fluorescent layers 21. The black matrix 22 is filled between one fluorescent layer 21 and another fluorescent layer 21 which are adjacent to each other, for improving a contrast.

[0181] As Fig. 10 shows a conceptual exploded view of the flat-panel display, in the flat-panel display of Example 2, the first panel P_1 (display panel) and the second panel P_2 are opposed to each other through the vacuum layer VAC and bonded to each other through the frame 24 in their circumferential portions. Fig. 10 indicates the bonding portion with section lines. Each of the first panel P_1 and the second panel P_2 is functionally largely classified into the effective field EF_1 or EF_2 (indicated by slanting lines) which has the pixels arranged therein and works as an actual display portion and a non-effective field NE_1 or NE_2 which surrounds the effective field EF_1 or EF_2 and has peripheral circuits, etc., for selecting the pixels. Other through hole 16 for vacuuming is provided in the non-effective field NE_1, and the tip tube 17 which is to be sealed after vacuuming is connected to the through hole 16. The vacuum layer VAC has a vacuum degree on the order of 10^{-4} to 10^{-6} Pa.

[0182] As shown in Fig. 11, an electrically conductive material layer for a cathode electrode in the form of a stripe (electrically conductive material layer for a cathode electrode) and an electrically conductive material layer for a gate electrode in the form of a stripe are formed in directions in which the projection images of these layers cross each other at right angles. In Example 2, a plurality of the field emission devices are arranged in a region where the projection images of the above layers in the form of stripes overlap. Such a region corresponds to one pixel and is an electron-emitting region. Further, such electron-emitting regions are generally arranged in the effective field EF_1 of the first panel P_1 so as to form a two-dimensional matrix. One pixel comprises the electron-emitting region (having a plurality of field emission devices) where the electrically conductive material layer for a cathode electrode and the electrically conductive material layer for a gate electrode overlap and the fluorescent layer 21 which faces the electron-emitting region. In the effective fields EF_1 and EF_2, for example, such pixels on the order of hundreds of thousands to millions are arranged in the form of a two-dimensional matrix.

[0183] A relatively negative voltage is applied to the cathode electrode 11 from a scanning circuit 30, a relatively positive voltage is applied to the gate electrode 13 from a control circuit 31, and a positive voltage higher than the voltage applied to the gate electrode 13 is applied to the anode electrode 23 from an acceleration power source 32. When such a flat-panel display displays an image, a scanning signal is inputted to the cathode electrode 11 from the scanning circuit 30, and a video signal is inputted to the gate electrode 13 from the control circuit 31. When the gate electrode 13 and the cathode electrode 11 come to have a potential difference ΔV equal to, or higher than, a certain threshold voltage V_{th}, the potential difference ΔV causes an electric field, and on the basis of the electric field, electrons are emitted from the top end of the electron-emitting portion 15 owing to a quantum tunnel effect.

[0184] In the flat-panel display of Example 2, specifically, the electron-emitting regions arranged in the row direction (X-direction) are consecutively operated in the column direction (Y-direction). That is, a constant voltage V_G from the scanning circuit 31 is applied consecutively to the electrically conductive material layers for a gate electrode in the form of stripes where the gate electrodes 13 are formed. On the other hand, a voltage of $0 \le [V_{C\text{-}MAX}$ to $V_{C\text{-}MIN}]$ ($<V_G$) from the control circuit 30 is applied to each of the electrically conductive material layers for a cathode electrode in the form of stripes where the cathode electrodes 11 are formed. In a region where the electrically conductive material layer for a gate electrode in the form of a stripe where the voltage V_G is applied and the electrically conductive material layer

for a cathode electrode in the form of a stripe where the voltage of $V_{C\text{-}MAX}$ to $V_{C\text{-}MIN}$ is applied overlap, the potential difference ΔV comes to be the largest at (V_G - $V_{C\text{-}MIN}$), the amount of electrons emitted from the electron-emitting region comes to be the largest, and the electrons are attracted to the anode electrode 23 and collide with the fluorescent layer 21. A positive voltage higher than the voltage applied to the gate electrode 13 is applied to the anode electrode 23 from the acceleration power source 32. As a result, the fluorescent layer corresponding to such an electron-emitting region come to show a highest brightness. On the other hand, in (V_G - $V_{C\text{-}MAX}$), the potential difference ΔV comes to be the smallest, no electrons are emitted from the electron-emitting region, and the fluorescent layer corresponding to such an electron-emitting region emit no light. By applying a voltage of $V_{C\text{-}MAX}$ to $V_{C\text{-}MIN}$ to each electrically conductive material layer for a cathode electrode, the brightness of the fluorescent layer can be controlled.

[0185] In the flat-panel display having the above constitution, the second-type getters 43B are provided in the effective field EF_1 of the first panel P_1, more specifically, on the gate electrodes 13, so that a uniform gas-trapping effect can be secured for the Spindt-type field emission devices positioned all over in the effective field. In the above flat-panel display, local discharging and damaging of electron-emitting portions are prevented, and a longer lifetime and high-quality images can be achieved.

Example 3

[0186] Example 3 is a variant of Example 2. Example 3 differs from Example 2 mainly in that the third-type getters 43C each having a supporting member constituted of a porous material member 45 are formed.

[0187] Procedures up to the formation of the electrically conductive material layer 13' for a gate electrode are carried out in the same manner as in [Step-200] of Example 2, except that ITO is used as a material for a cathode electrode 11. Then, the getter-forming layer 43 is formed on the electrically conductive material layer 13' for a gate electrode. The getter-forming layer 43 comprises, from a lower layer side, the supporting member constituted of the porous material member 45 and the gas-trapping layer 42 formed on the porous material member 45 (see Fig. 1C). In Example 3, for example, a methylsiloxane solution is applied onto the entire surface by a spin coating method at 3000 rpm, and the obtained supporting-member-forming film is calcined or sintered around 500 °C, to form the porous material member 45 composed of silicon-oxide-containing xerogel. Then, the gas-trapping layer 42 composed of titanium (Ti) is formed on the porous material member 45, for example, by a sputtering method or a CVD method. Table 3 shows one example of a condition for forming the gas-trapping layer 42 composed of titanium (Ti) by a CVD method. Procedures to come thereafter can be carried out in the same manner as in Example 2 except that tungsten is used to form the electron-emitting portions 15. In Example 3, the flat-panel display shown in Figs. 9 to 11 can be constituted as well.

Table 3

[Condition for forming gas-trapping layer composed of titanium (Ti)]	
CVD Apparatus	Magnetic-field-possessing microwave plasma CVD apparatus
$TiCl_4$	15 SCCM
H_2 flow rate	50 SCCM
Ar flow rate	43 SCCM
Pressure	0.3 Pa
Microwave power	2.0 kW (2.45 GHz)
Forming temperature	420 °C

Example 4

[0188] Example 4 is a variant of Example 3. Example 4 differs from Example 3 mainly in that the porous material member 45 is formed by utilizing phase separation. In the step of forming the porous material member 45, first, for example, TEOS and trimethoxyboric acid in a TEOS/trimethoxyboric acid weight ratio of 10/3 are dissolved in ethanol, and the ethanol solution is coated on the entire surface by a spin coating method at approximately 3000 rpm. Then, the obtained supporting-member-forming film is subjected to temporary calcining or sintering around 200 °C to remove an organic substance contained in the solution. Further, the film is further subjected to main calcining or sintering around 500 °C to give a state, by phase separation, where fine particles of boron oxide are precipitated in a borosilicate glass. Then, etching with hot water is carried out, whereby only the fine particles of boron oxide are dissolved and removed, and the porous material member 45 composed of a borosilicate glass is obtained. Procedure to come thereafter can be carried out in the same manner as in Example 3. In Example 4, the flat-panel display shown in Figs. 9 to

11 can be constituted as well.

Example 5

[0189] Example 5 is another variant of Example 3. Example 5 differs from Example 3 mainly in that the porous material member 45 is formed by removing a component having a relatively high etching rate by etching. In the step of forming the porous material member 45, first, for example, TEOS and methyltrimethoxysilane in a TEOS/methyltrimethoxy silane weight ratio of 10/4 are dissolved in ethanol, and the ethanol solution is coated on the entire surface by a spin coating method at approximately 3000 rpm. Then, the obtained supporting-member-forming film is subjected to calcining or sintering around 200 °C to remove an organic substance contained in the solution. In the supporting-member-forming film obtained in this case, silicon oxide derived from TEOS and silicon oxide derived from methyltrimethoxysilane are co-present. Then, etching is carried out with a 1 % hydrofluoric acid aqueous solution, whereby the silicon oxide derived from methyltrimethoxysilane having a relatively high etching rate is removed by the etching, and the porous material member 45 of silicon oxide derived from TEOS can be obtained. Procedure to come thereafter can be carried out in the same manner as in Example 3. In Example 5, the flat-panel display shown in Figs. 9 to 11 can be constituted as well.

Example 6

[0190] Example 6 is concerned with the production method according to the second constitution of the present invention and the flat-panel display according to the second constitution of the present invention obtained by the above production method. Example 6 will be explained with reference to Figs. 12A, 12B, 13A and 13B hereinafter.

[Step-600]

[0191] Procedures up to the formation of an insulating layer 12 are carried out in the same manner as in [Step-200] of Example 2. Then, a gate electrode 13 is formed on the insulating layer 12. The gate electrode 13 can be obtained by forming the electrically conductive material layer 13' for a gate electrode and patterning the electrically conductive material layer 13' by an etching method, etc., as described in Example 2, or can be formed directly in the form of a stripe by a screen-printing method. Then, an approximately 1 μm thick second insulating layer 46 composed of SiO_2 is formed on the gate electrode 13 and the insulating layer 12, for example, by a CVD method. Further, an approximately 0.07 μm thick TiN layer is formed on the entire surface on the second insulating layer 46 by a sputtering method, to form an electrically conductive material layer for a focus electrode (electrically conductive material layer 47' for a focus electrode). Further, a getter-forming layer 43 is formed on the electrically conductive material layer 47' for a focus electrode in the same manner as in [Step-200] of Example 2 (see Fig. 12A).

[Step-610]

[0192] Then, as shown in Fig. 12B, the getter-forming layer 43 and the electrically conductive material layer 47' for a focus electrode are patterned, whereby a focus electrode 47 having the second-type getter 43B formed on the upper surface thereof can be formed. The patterning is carried out, for example, by etching the getter-forming layer 43 and the electrically conductive material layer 47' for a focus electrode through an etching mask (not shown).

[Step-620]

[0193] Then, as shown in Fig. 13A, the second insulating layer 46, the gate electrode 13 and the insulating layer 12 are patterned, to form an opening portion 14 having the cathode electrode 11 exposed in a bottom portion thereof. The opening portion 14 can be formed, for example, by etching the second insulating layer 46, the gate electrode 13 and the insulating layer 12 through an etching mask (not shown). In this case, the above patterning is carried out inside the opening portion formed in the focus electrode 47, whereby an end portion of the focus electrode 47 can be allowed to recede from the end portion of the gate electrode 13. The focus electrode 47 is originally provided to correct only the path of electrons which deviate from the direction perpendicular to the cathode electrode 11 to a great extent, and when the opening diameter of the focus electrode 47 is too small, the electron emission efficiency of the field emission device may decrease. Particularly preferably, the end portion of the focus electrode 47 recedes from the end portion of the gate electrode 13 as described above, since the necessary focusing effect alone can be produced without hindering the emission of electrons.

[Step-630]

[0194] Then, steps similar to [Step-230] to [Step-250] of Example 2 are carried out, to form a conical electron-emitting portion 15 in a portion of the cathode electrode 11 which portion is positioned in a bottom portion of the opening portion 14 and to allow a side wall surface of the opening portion 14 formed in the insulating layer 12 and the second insulating layer 46 to recede under an isotropic etching condition, whereby a field emission device shown in Fig. 13B can be completed. Further, a step similar to [Step-260] of Example 2 is carried out, whereby a flat-panel display similar to one explained in Example 2 can be obtained in Example 6. In such a flat-panel display, the convergence of the path of emitted electrons is improved and an optical crosstalk among the pixels is therefore decreased, so that a higher fineness of a display screen can be attained by more finely dividing each pixel. The second-type getter 43B may be replaced with the first-type getter 43A or the third-type getter 43C.

Example 7

[0195] Example 7 is concerned with the production method according to the third constitution of the present invention and the flat-panel display according to the first constitution of the present invention obtained by the above production method. Example 7 will be explained with reference to Figs. 14A and 14B below.

[Step-700]

[0196] Procedures up to the formation of the insulating layer 12 are carried out in the same manner as in [Step-200] of Example 2. As shown in Fig. 14A, then, a gate electrode 13 is formed on the insulating layer 12. The gate electrode 13 can be obtained by forming the electrically conductive material layer 13' for a gate electrode and then patterning the electrically conductive material layer 13' according to an etching method, etc., as described in Example 2, or it can be also formed directly in the form of a stripe by a screen-printing method.

[Step-710]

[0197] As shown in Fig. 14B, then, the second-type getter 43B is formed on the gate electrode 13. The second-type getter 43B may be formed by a method in which the second-type getters 43B can be formed only on the gate electrodes 13 or by a method in which a getter-forming layer 43 is formed on the entire surface and the getter-forming layer 43 is patterned. Since procedures thereafter can be carried out in the same manner as in [Step-220] to [Step-260] of Example 2, detailed explanations thereof are omitted. In Example 7, the flat-panel display shown in Figs. 9 to 11 can be constituted as well.

[0198] Figs. 15A to 15C show three patterns of formed getters. Fig. 15A shows a second-type getter 43B which is positioned on the gate electrode 13 and extends onto the insulating layer 12. Fig. 15B shows a second-type getter 43B which is positioned on an insulating layer 12 between one gate electrode 13 and another gate electrode 13 which are adjacent to each other. Fig. 15C shows a second-type getter 43B formed on the entire surface on the gate electrode 13 and the insulating layer 12. As a getter, the second-type getter 43B may be replaced with the first-type getter 43A or the third-type getter 43C. While the getter pattern shown in Fig. 15C is a pattern which can give a maximum effective area of the getter, the supporting member is required to have electrically insulating properties for preventing short-circuiting between the adjacent gate electrodes 13. The supporting member having electrically insulating properties includes a structure constituted of an electrically insulating material layer; a polycrystalline silicon layer and nearly hemispherical silicon particles; a porous material member 45 composed of an electrically insulating layer; and an electrically conductive porous material member 45 formed on an electrically insulating material layer. In the production method according to the third constitution of the present invention, the gate electrode is formed in one step, and the getter is formed in another step, so that it can be said that an example in which the pattern of the gate electrodes 13 and the pattern of the getters differ from each other more effectively utilizes the characteristic of the production method according to the third constitution.

Example 8

[0199] Example 8 is concerned with the production method according to the fourth constitution of the present invention and the flat-panel display according to the second constitution of the present invention obtained by the above production method. Only the difference of Example 8 from Example 6 will be explained with reference to Figs. 16A and 16B.

[Step-800]

[0200] Procedures up to the formation of the second insulating layer 46 are carried out in the same manner as in [Step-600] of Example 6. Then, a focus electrode 47 is formed on the second insulating layer 46 (see Fig. 16A). The focus electrode 47 can be obtained by forming the electrically conductive material layer 47' for a focus electrode and then patterning the electrically conductive material layer 47' by an etching method, etc., as described in Example 6, or it can be also formed directly in the form of a stripe by a screen-printing method.

[Step-810]

[0201] As shown in Fig. 16B, then, the second-type getter 43B is formed on the focus electrode 47. The second-type getter 43B can be formed by a method in which the second-type getter 43B can be selectively formed on the focus electrode 47 alone or by a method in which a getter-forming layer 43 is formed on the entire surface and the getter-forming layer 43 is patterned. Since procedures thereafter can be carried out in the same manner as in [Step-620] to [Step-630] of Example 6, detailed explanations thereof are omitted. In Example 8, the flat-panel display similar to that described in Example 6 can be constituted as well.

[0202] Figs. 17A to 17C show three patterns of formed getters. Fig. 17A shows a second-type getter 43B which is positioned on the focus electrode 47 and extends onto the second insulating layer 46. Fig. 17B shows a second-type getter 43B which is positioned on the second insulating layer 46 between one focus electrode 47 and another focus electrode 47 which are adjacent to each other. Fig. 17C shows a second-type getter 43B formed on the entire surface on the focus electrode 47 and the second insulating layer 46. As a getter, the second-type getter 43B may be replaced with the first-type getter 43A or the third-type getter 43C. While the getter pattern shown in Fig. 17C is a pattern which can give a maximum effective area of the getter, the supporting member is required to have electrically insulating properties for preventing short-circuiting between the adjacent focus electrodes 47. The supporting member having electrically insulating properties includes a structure constituted of an electrically insulating material layer; a polycrystalline silicon layer and nearly hemispherical silicon particles; a porous material member 45 constituted of an electrically insulating layer; and an electrically conductive porous material member 45 formed on an electrically insulating material layer. In the production method according to the fourth constitution of the present invention, the focus electrode 47 is formed in one step, and the getter is formed in another step, so that it can be said that an example in which the pattern of the focus electrodes 47 and the pattern of the getters differ from each other more effectively utilizes the characteristic of the production method according to the fourth constitution.

Example 9

[0203] Example 9 is concerned with the production method according to the fifth constitution of the present invention and the flat-panel display according to the third constitution of the present invention obtained by the above production method. In Example 9, at least part of the gate electrode is composed of a gas-trapping material. Specifically, Example 9 uses a zirconium-aluminum alloy (Zr-Al alloy) as a gas-trapping material for constituting a gate electrode 113, and the gate electrode 113 has a single-layered structure. Example 9 will be explained with reference to Figs. 18A and 18B hereinafter.

[Step-900]

[0204] First, a cathode electrode 11 constituted of an electrically conductive material layer of niobium (Nb) in the form of a stripe is formed on a supporting substrate 10 made, for example, of glass, and an insulating layer 12 composed of SiO_2 is formed on the entire surface. Further, the gate electrode 113 constituted of an electrically conductive material layer of a zirconium-aluminum alloy (Zr-Al alloy) as a gas-trapping material in the form of a stripe is formed on the insulating layer 12. The gate electrode 113 can be formed, for example, by a sputtering method, lithography and a dry etching method. Then, an opening portion 14 is formed in the gate electrode 113 and the insulating layer 12 by an RIE (reactive ion-etching) method, to expose the cathode electrode 11 in a bottom portion of the opening portion 14 (see Fig. 18A). The cathode electrode 11 may be a single material layer, or it may be a stack of a plurality of material layers. For suppressing the fluctuation of electron emission characteristics of the electron-emitting portions to be formed at a step to come later, the surface layer portion of the cathode electrode 11 can be composed of a material having a higher electric resistivity than a material forming a remaining portion. Such a structure of the cathode electrode can be applied to the field emission device in other Examples.

[Step-910]

[0205] Thereafter, procedures in [Step-230] to [Step-250] in Example 2 are carried out, whereby a Spindt-type field emission device having a structure shown in Fig. 18B can be completed.

[0206] Figs. 19A, 19B, 20A, 20B and 20C show variants of the gate electrode.

[0207] The gate electrode shown in Fig. 19A does not have a single-layered structure but has a stacked structure constituted of a first layer 113A composed of an electrically conductive material such as nickel (Ni) and a second layer 113B composed of a gas-trapping material. The first layer 113A may be composed of an electrically insulating material such as a glass. In this case, however, the second layer 113B is required to have electric conductivity.

[0208] The gate electrode shown in Fig. 19B has a stacked structure constituted of a first layer 113A composed of an electrically conductive material or a gas-trapping material, a second layer 113B composed of an electrically insulating material and a third layer 113C composed of a gas-trapping material (gas-trapping layer).

[0209] The gate electrode shown in Fig. 20A has a stacked structure constituted of a first layer 113A composed of an electrically conductive material and a second layer 113B composed of a gas-trapping material. Differing from the gate electrode shown in Fig. 19A, the gate electrode has a structure in which the upper end portion of the opening portion 14 formed in the first layer 113A has a smaller opening size than the lower end portion thereof. When electrons emitted from the electron-emitting portion 15 enters the insulating layer 12 near the first layer 113A, gas may be released from such a portion of the insulating layer 12. In the above structure, the risk of electrons colliding with the insulating layer 12 decreases even if the path of electrons curves toward the inner side wall of the first layer 113A, so that the release of the gas from the insulating layer 12 can be prevented.

[0210] The gate electrode shown in Fig. 20B also has a stacked structure constituted of a first layer 113A composed of an electrically conductive material and a second layer 113B composed of a gas-trapping material. Differing from the gate electrode shown in Fig. 19A, the gate electrode has a structure in which the upper end portion of the opening portion 14 formed in the first layer 113A has a larger opening size than the lower end portion thereof.

[0211] The gate electrode shown in Fig. 20C also has a stacked structure constituted of a first layer 113A composed of an electrically conductive material and a second layer 113B composed of a gas-trapping material. Differing from the gate electrode shown in Fig. 19A, the gate electrode has a structure in which the upper end portion of the opening portion 14 formed in the first layer 113A has a larger opening size than the lower end portion thereof and the opening end side wall of the first layer 113A is covered with second layer 113B. In such a structure, the opening end side wall of the opening portion 14 which serves as a path of electrons in the gate electrode is brought into a state where the opening end side wall is all covered with the second layer 113B composed of a gas-trapping material, so that no gas is released from the gate electrode even if electrons collide with the opening end side wall since a portion with which electrons collide is necessarily composed of the gas-trapping material.

[0212] In the gate electrodes shown in Figs. 20A to 20C, a slanted opening end side wall of the first layer 113A can be formed by optimizing a condition for etching the first layer 113A.

[0213] The function of the gate electrode 113 produced by containing a gas-trapping material will be explained more in detail below with reference to Figs. 21A, 21B and 21C.

[0214] Fig. 21A shows an example of a pressure distribution when gas molecules, etc., are released by the collision of electrons with the fluorescent layer 21 to increase a pressure up to approximately l Pa near the fluorescent layer 21. Even when gas molecules, etc., are released near the fluorescent layer 21 to increase the pressure, the released gas molecules, etc., are trapped by the gas-trapping material of a gate electrode 113. Therefore, the pressure of the vacuum layer decreases toward the electron-emitting portion 15, so that local discharging, etc., which are involved in the releasing of the gas molecules, etc., is prevented, and the detrimental effect on the electron-emitting portion 15 is prevented.

[0215] Fig. 21B shows an example of a pressure distribution near the electron-emitting portion 15 when gas molecules, etc., released by the collision of electrons with the fluorescent layer 21 reach the electron-emitting portion 15 to cause gas molecules, etc., to be released from the electron-emitting portion 15. Even when gas molecules, etc., are released in a site H_1 near the electron-emitting portion 15, the released gas molecules, etc., are trapped by the gas-trapping material of the gate electrode 113. A pressure in the site H_1 near the electron-emitting portion 15, therefore, increases, for example, approximately by 2×10^{-4} Pa, and the pressure is not increased so high as to affect the electron-emitting portion 15.

[0216] Fig. 21C shows an example of a pressure distribution when gas molecules, etc., are released by the collision of electrons with the fluorescent layer 21 and further when gas molecules, etc., are released from the insulating layer 12 by the collision of electrons emitted from the electron-emitting portion and distracted toward the insulating layer 12 with a wall surface H_2 of the insulating layer 12. Even if the gas molecules, etc., are released from the wall surface H_2 of the insulating layer 12, the released gas molecules, etc., are trapped by the gate electrode 113, so that a pressure increases, for example, approximately by 2×10^{-3} Pa. Further, the pressure decreases toward the electron-emitting portion 15, and the detrimental effect on the electron-emitting portion 15 is prevented.

Example 10

[0217] Example 10 is concerned with the production method according to the sixth constitution of the present invention and the flat-panel display according to the fourth constitution of the present invention obtained by the above production method. In Example 10, at least part of the focus electrode is composed of a gas-trapping material. Specifically, the gas-trapping material constituting a focus electrode 147 is a zirconium-aluminum alloy (Zr-Al alloy), and the focus electrode 147 has a single-layered structure. Example 10 will be explained with reference to Figs. 22A and 22B hereinafter.

[Step-1000]

[0218] Procedures up to the formation of an insulating layer 12 are carried out in the same manner as in [Step-200] of Example 2. Then, a gate electrode 13 is formed on the insulating layer 12. The gate electrode 13 can be obtained by forming the electrically conductive material layer 13' for a gate electrode and then patterning the electrically conductive material layer 13' according to an etching method, etc., as described in Example 2, or it can be also formed directly in the form of a stripe by a screen-printing method. Then, an approximately 1 μm thick second insulating layer 46 composed of SiO_2 is formed on the gate electrode 13 and the insulating layer 12, for example, by a CVD method. Further, the focus electrode 147 composed of a zirconium-aluminum alloy (Zr-Al alloy) as a gas-trapping material is formed in the form of a stripe on the second insulating layer 46. The focus electrode 147 can be formed, for example, by a sputtering method, lithography or a dry etching method (see Fig. 22A).

[Step-1010]

[0219] Then, steps similar to [Step-620] to [Step-630] of Example 6 are carried out, whereby a Spindt-type field emission device having a structure shown in Fig. 22B can be completed.
[0220] The focus electrode 147 can be formed so as to have any one of structures shown in Figs. 19A, 19B, 20A, 20B and 20C.

Example 11

[0221] Example 11 is concerned with the production method according to the seventh constitution of the present invention and the flat-panel display according to the fifth constitution of the present invention obtained by the above production method. The field emission device of the flat-panel display of Example 11 comprises:

(A) a spacer 12 disposed on a supporting substrate 10 and composed of an electrically insulating material,
(B) a gate electrode 213 constituted of a gas-trapping material layer 213A which has a plurality of opening portions 214A formed therein and at least part of which is composed of a gas-trapping material, and
(C) an electron-emitting portion 15C formed on the supporting substrate 10,

wherein the gas-trapping material layer 213A is fixed such that it comes in contact with the top surface of the spacer 12 and that the opening portion 214A is positioned above the electron-emitting portion 15C.
[0222] The gas-trapping material layer 213A is fixed to the top surface of the spacer with a thermosetting adhesive (for example, an epoxy-containing adhesive). Alternatively, as shown in Fig. 23 showing a schematic partial cross-sectional view of an end portion of the supporting substrate 10, there may be employed a structure in which each end portion of the gas-trapping material layer 213A in the form of a stripe is fixed to a circumferential portion of the supporting substrate 10. More specifically, for example, projection portions 216 are formed beforehand in the circumferential portion of the supporting substrate 10, a thin film 217 composed of the same material as that used for constituting the gas-trapping material layer 213A is formed on the top surface of the projection portion 216 beforehand, and the gas-trapping material layer 213A in the form of a stripe is welded to the thin film 217 with a laser while it is in an expanded state. The projection portion 216 can be formed concurrently with the formation of the spacer.
[0223] As the gas-trapping material layer 213A in Example 11, a stacked structure constituted of a first layer composed of nickel (Ni) as an electrically conductive material and a second layer composed of a gas-trapping material is used. The gas-trapping material layer 213A shall not be limited to the stacked structure, and it may have a single-layered structure. In this case, examples of the material for the gas-trapping material layer 213A include titanium (Ti), titanium alloys such as a titanium-zirconium-vanadium-iron (Ti-Zr-V-Fe) alloy, carbon (C) and barium (Ba). When a stacked structure is used as the gas-trapping material layer 213A, it is preferred to form the second layer composed of a gas-trapping material on the cathode electrode side, since a vacuum state around the cathode electrode 211 can be maintained in a good condition. That is, it is preferred to reverse the order of stacking of the first layer 113A and

the second layer 113B in the Figs. 19A, 20A, 20B and 20C.

[0224] In Example 11, a plane-type field emission device is used as a field emission device. The plane-type field emission device comprises a cathode electrode 211 formed in the form of a stripe on a supporting substrate 10 made, for example, of a glass; an insulating layer 12 (corresponding to the spacer) formed on the supporting substrate 10 and the cathode electrode 211; a gate electrode 213 formed in the form of a stripe on the insulating layer 12; and an opening portion 214 which is formed through the gate electrode 213 and the insulating layer 12 and has the cathode electrode 211 exposed in the bottom portion thereof. The cathode electrode 211 extends in the direction perpendicular to the paper surface of Fig. 23, and the gate electrode 213 extends leftward and rightward on the paper surface of Fig. 23. The cathode electrode 211 is composed of chromium (Cr), and the insulating layer 12 is composed of SiO_2. In this case, that part of the cathode electrode 211 which is exposed in the bottom portion of the opening portion 214 corresponds to an electron-emitting portion 15C and corresponds to an electron-emitting layer.

[0225] One example of the method of producing the field emission device in Example 11 will be explained below.

[Step-1100]

[0226] First, the cathode electrode 211 which works as an electron-emitting portion 15C is formed on the supporting substrate 10. Specifically, an electrically conductive material layer composed of chromium (Cr) for a cathode electrode is formed on the supporting substrate 10 by a sputtering method, and the electrically conductive material layer for a cathode electrode is patterned by lithography and a dry etching method, whereby the cathode electrode 211 composed of the electrically conductive material layer in the form of a stripe can be formed on the supporting substrate 10.

[Step-1110]

[0227] Then, an insulating layer 12 (corresponding to the spacer) composed of SiO_2 is formed on the entire surface, specifically, on the supporting substrate 10 and the cathode electrode 211, by a CVD method. Alternatively, the insulating layer 12 may be formed from a glass paste by a screen-printing method.

[Step-1120]

[0228] Then, the opening portion 214 is formed in the insulating layer 12 by lithography and an etching method. Otherwise, the opening portion 214 may be formed together when the insulating layer 12 is formed by a screen-printing method. In this manner, the surface of the cathode electrode 211 which surface corresponds to the electron-emitting portion can be exposed in the bottom portion of the opening portion 214. The insulating layer 12 corresponds to the spacer.

[Step-1130]

[0229] Then, the stripe-shaped gas-trapping material layer 213A having a plurality of the opening portions 214A is disposed in a state in which it is supported on the insulating layer 12 such that the opening portions 214A are positioned above the electron-emitting portion and that the stripe-shaped gas-trapping material layer 213A is disposed in a direction different from a direction in which the cathode electrode 211 extends. In this manner, the gate electrode 213 which is constituted of the gas-trapping material layer 213A in the form of a stripe and has a plurality of the opening portions 214A is positioned above the electron-emitting portion.

[0230] A stripe-shaped material layer for a gate electrode 213 can be prepared, for example, by the following method. That is, a nickel sheet for a first layer 113A is provided, a gas-trapping material (such as titanium or a titanium-containing alloy such as a titanium-zirconium-vanadium-iron alloy) is, for example, applied to, or deposited on. the nickel sheet to form a second layer 113B. Then, the opening portions 214A having a predetermined form are formed in the first layer 113A and the second layer 113B. There may be employed procedures of forming the opening portions 214A in the first layer 113A in advance and then forming the second layer 113B thereon. Preferably, the second layer 113B is formed in a vacuum atmosphere or an atmosphere of an inert gas such as argon (Ar) or helium (He) in order to prevent the second layer 113B from trapping an unnecessary substance before the first panel P_1 and the second panel P_2 are bonded.

[0231] The gas-trapping material layer 213A may be composed of a gas-trapping material whose gas-trapping capability increases with an increase in temperature, such as a zirconium-aluminum alloy or a titanium-zirconium-vanadium-iron alloy. Fig. 24 shows a relationship between a temperature of a zirconium-aluminum alloy (Al-Zr alloy) and a vacuuming rate in the internal space of the flat-panel display. In Fig. 24, the axis of abscissas indicates temperatures (°C), and the axis of ordinates indicates a vacuuming rate which is a rate of the Al-Zr alloy trapping gas molecules, etc., in the internal space, and its unit is ml/second•cm^2. As is clearly shown in Fig. 24, the Al-Zr alloy has the property

of increasing its vacuuming rate with an increase in temperature (that is, the gas-trapping capability thereof increases). Even if electrons emitted from the electron-emitting portion 15C are curved toward the gate electrode 213 and collide with the gate electrode 213 to cause the temperature increase of the gate electrode 213, the Al-Zr alloy incorporated into the gate electrode 213 makes it possible to expect an effect that the vacuuming rate in the gate electrode 213 increases, and the unstable performance caused on the flat-panel display by an increase in temperature can be prevented. When it is intended to utilize the above effect actively, preferably, not the first layer 113A but the second layer 113B has such a form that electrons easily collide with it when the gate electrode 213 has a stacked structure of the first layer 113A and the second layer 113B. When there is employed a constitution in which the first layer 113A is covered with the second layer 113B as shown in Fig. 20C, electrons inevitably enter the second layer 113B, and there can be expected the effect that the vacuuming rate is improved by an increase in temperature. For activating the Al-Zr alloy to impart it with the vacuuming function, it is at least required to heat the Al-Zr alloy to 300 °C or higher. The activation is preferably carried out by heat treatment in a vacuum atmosphere or an atmosphere of an inert gas such as argon or helium after the formation of the gas-trapping material layer 213A but before [Step-1130]. The above heat treatment can be carried out by irradiating the second layer 113B with electron beam. Otherwise, it can be carried out by introducing the gas-trapping material layer 213A into a generally employed high-temperature furnace.

[0232] The above method of forming the gate electrode can be applied to the production of various field emission devices.

Example 12

[0233] Example 12 is a variant of Example 11. The field emission device in Example 12 differs from the field emission device in Example 11 in that a rib 212 (corresponding to a spacer) is provided between one cathode electrode 211 and another cathode electrode 211 as is shown in a schematic partial cross-sectional view of Fig. 25A. Fig. 25B shows a schematic layout of the cathode electrodes 211, gas-trapping material layers 213A with the gate electrodes 213 and the ribs 212. When a stacked structure is employed as the gas-trapping material layer 213A in the form of a stripe, preferably, the second layer composed of the gas-trapping material is positioned on the cathode electrode side from the viewpoint that the vacuum state around the cathode electrode 211 is maintained under a good condition.

[0234] The gas-trapping material layer 213A is fixed to the top surface of the ribs 212 with a thermosetting adhesive (for example, an epoxy-containing adhesive). Otherwise, there may be employed a structure in which both ends of the gas-trapping material layer 213A in the form of a stripe are fixed to the circumferential portion of the supporting substrate 10 as shown in the schematic partial cross-sectional view of Fig. 23. More specifically, projection portions 216 are formed in the circumferential portion of the supporting substrate 10 beforehand, and a thin film 217 composed of the same material as that used for the gas-trapping material layer 213A is formed on the top surface of the projection portion 216 beforehand. While the gas-trapping material layer 213A in the form of a stripe is in an expanded state, the gas-trapping material layer 213A is welded to the thin film 217, for example, with a laser.

[0235] The field emission device in Example 12 can be prepared, for example, by the following method.

[Step-1200]

[0236] The rib 212 constituting a spacer (gate electrode support) in the form of a stripe is formed on the supporting substrate 10, for example, by a sandblasting method.

[Step-1210]

[0237] Then. an electron-emitting portion is formed on the supporting substrate 10. Specifically, a mask layer composed of a resist material is formed on the entire surface by a spin coating method, and the mask layer is removed from a region where the cathode electrode is to be formed and which is between one rib 212 and another rib 212. Then, an electrically conductive material layer composed of chromium (Cr) for a cathode electrode is formed on the entire surface by a sputtering method in the same manner as in [Step-1100], and then the mask layer is removed, whereby the electrically conductive material layer formed on the mask layer is also removed and the cathode electrode 211 which works as an electron-emitting portion is retained between one rib 212 and another rib 212.

[Step-1220]

[0238] The stripe-shaped gas-trapping material layer 213A having a plurality of the opening portions 214A is disposed in a state in which it is supported on the ribs 212, which are the spacers, such that a plurality of the opening portions 214A are positioned above the electron-emitting portion, whereby the gate electrode 213 which is constituted of the gas-trapping material layer 213A in the form of a stripe and has a plurality of the opening portions 214A is positioned

above the electron-emitting portion. The gas-trapping material layer 213A in the form of a stripe can be arranged as described above.

[0239] The above method of forming the gate electrode can be applied to the production of various field emission devices.

[0240] In the field emission device in Example 11 or 12, the plane form of the opening portions 214A is not limited to a circular form. Figs. 26A, 26B, 26C and 26D show variants of the form of the opening portions 214A formed in the gas-trapping material layer 213A.

Example 13

[0241] Examples 13 to 27 will explain field emission devices having various constitutions and structures and methods for the production thereof. All of these field emission devices can be applied to the flat-panel displays explained in Examples 1 to 12. That is, all of the gate electrode and the getter in the field emission device constituting the flat-panel display according to the first constitution and the gate electrode in the field emission device constituting the flat-panel displays according to the third and fifth constitutions can be applied to Examples 13 to 27. The above gate electrode/ getter or the above gate electrode will be expressed as a gate electrode 313 or 313B and is indicated by such a reference numeral in Figures. The gate electrode 313 or 313B can be formed and produced according to any method explained in Examples 1 to 12. Further, Examples 13 to 27 may use the focus electrode explained in any one of Examples 6, 8 and 10.

[0242] In addition to the foregoing Spindt type field emission device (a conical electron-emitting portion is formed on that portion of a cathode electrode which is positioned in the bottom portion of an opening portion), the field emission device includes a crown-type field emission device (a crown-shaped electron-emitting portion is formed on that portion of a cathode electrode which is positioned in the bottom portion of an opening portion), a flat-type field emission device (a nearly flat electron-emitting portion is formed on that portion of a cathode electrode which is positioned in the bottom portion of an opening portion), a plane-type field emission device which is for emitting electrons from a flat surface of a cathode electrode, a crater-type field emission device which is for emitting electrons from a convex portion of surface of a cathode electrode having a convexo-concave surface, and an edge-type field emission device.

[0243] First, the crown-type field emission device and the method of producing the same will be explained below.

[0244] Fig. 29A shows a schematic partial end view of the crown-type field emission device, and Fig. 29B shows a partially cut-out schematic perspective view thereof. The crown-type field emission device comprises a cathode electrode II formed on a supporting substrate 10; an insulating layer 12 formed on the supporting substrate 10 and the cathode electrode 11; a gate electrode 313 formed on the insulating layer 12; an opening portion 14 which penetrates through the gate electrode 313 and is formed in the insulating layer 12; and a crown-type electron-emitting portion 15A in a portion of the cathode electrode 11 which portion is positioned in a bottom portion of the opening portion 14.

[0245] The method of producing the crown-type field emission device will be explained below with reference to Figs. 27A, 27B, 28A, 28B, 28C, 28D, 29A and 29B showing schematic partial end views, etc., of the supporting substrate and the like.

[Step-1300]

[0246] First, the cathode electrode 11 constituted of an electrically conductive material layer for a cathode electrode in the form of a stripe is formed on the supporting substrate 10 made, for example, of a glass. The cathode electrode 11 extends leftward and rightward on a paper surface of drawings. The electrically conductive material layer for a cathode electrode in the form of a stripe can be obtained, for example, by forming an approximately 0.2 μm thick ITO film on the entire surface of the supporting substrate 10 and then patterning the ITO film. The cathode electrode 11 can be a single material layer or a stacked structure constituted of a plurality of material layers. For example, for suppressing the fluctuation of electron emission characteristics of the electron-emitting portions to be formed at a step to come later, the surface layer portion of the cathode electrode 11 may be composed of a material having a higher electric resistivity than a material constituting a remaining portion. Then, the insulating layer 12 is formed on the entire surface, specifically, on the supporting substrate 10 and the cathode electrode 11. In this embodiment, for example, a glass paste having a thickness of approximately 3 μm is screen-printed on the entire surface. Then, for removing water and a solvent contained in the insulating layer 12 and flattening the insulating layer 12, two-stage calcining or sintering procedures such as temporary calcining or sintering at 100 °C for 10 minutes and main calcining or sintering at 500 °C for 20 minutes are carried out. The above screen-printing using a glass paste may be replaced with the formation of an SiO_2 film, for example, by a CVD method.

[0247] Then, the gate electrode 313 is formed on the insulating layer 12 (see Fig. 27A). The gate electrode 313 is extending in the direction perpendicular to the paper surface of drawings. The material for the gate electrode 313 can be selected from those explained in the foregoing Spindt-type field emission device. The extending direction of pro-

jection image of the gate electrode 313 forms an angle of 90° with the extending direction of projection image of the cathode electrode 11 in the form of a stripe.

[Step-1310]

[0248] The gate electrode 313 and the insulating layer 12 are etched through an etching mask EM composed, for example, of a photoresist material according to an RIE method, to form an opening portion 14 through the gate electrode 313 and the insulating layer 12 and to expose the cathode electrode 11 in the bottom portion of the opening portion 14 (see Fig. 27B). The opening portion 14 has a diameter of approximately 2 to 50μm.

[Step-1320]

[0249] Then, the etching mask EM is removed, and a peel layer 51 is formed on the gate electrode 313, the insulating layer 12 and the side wall surface of the opening portion 14 (see Fig. 28A). The above peel layer 51 is formed, for example, by applying a photoresist material onto the entire surface by a spin coating method and patterning the photoresist material layer such that only part on the bottom portion of the opening portion 14 is removed. At this stage, the diameter of the opening portion 14 is substantially decreased to approximately 1 to 20 μm.

[Step-1330]

[0250] Then, as shown in Fig. 28B, an electrically conductive composition layer 52 composed of a composition material is formed on the entire surface. The above composition material contains, for example, 60 % by weight of graphite particles having an average particle diameter of approximately 0.1 μm as electrically conductive particles and 40 % by weight of No. 4 water glass as a binder. The composition material is spin coated on the entire surface, for example, at 1400 rpm for 10 seconds. The surface of the electrically conductive composition layer 52 in the opening portion 14 rises along the side wall surface of the opening portion 14 and dents toward the central portion of the opening portion 14 due to the surface tension of the composition material. Then, temporary calcining or sintering for removing water contained in the electrically conductive composition layer 52 is carried out, for example, in atmosphere at 400 °C for 30 minutes.

[0251] In the composition material, (1) the binder may be a dispersing medium which forms a dispersion for the electrically conductive particles in itself, or (2) the binder may coat each electrically conductive particle, or (3) the binder may constitute a dispersing medium for the electrically conductive particles when the binder is dispersed or dissolved in a proper solvent. A typical example of the above case (3) is water glass, and the water glass can be selected from Nos. 1 to 4 defined under Japan Industrial Standard (JIS) K1408 or products equivalent thereto. Nos. 1 to 4 refer to four grades based on different molar amounts (approximately 2 to 4 mols) of silicon oxide (SiO_2) per one mol of sodium oxide (Na_2O) which components of water glass, and differ from one another in viscosity. When water glass is used in a lift-off process, therefore, it is preferred to select an optimum water glass while taking into account various conditions such as a kind and a content of the electrically conductive particles to be dispersed in water glass, affinity to the peel layer 51, an aspect ratio of the opening portion 14, and the like, or it is preferred to prepare water glass equivalent to such a grade before use.

[0252] The binder is generally poor in electric conductivity. When the content of the binder is too large relative to the content of the electrically conductive particles in the electrically conductive composition, therefore, the electron-emitting portion 15A formed may show an increase in electric resistance value, and electron emission may not proceed smoothly. For example, in a composition material which is a dispersion of carbon-containing material particles as electrically conductive particles in water glass, the content of the carbon-containing material particles based on the total amount of the composition material is preferably determined to be in the range of approximately 30 to 95 % by weight while taking into account properties such as an electric resistance value of the electron-emitting portion 15A, a viscosity of the composition material and mutual adhesion of the electrically conductive particles. When the content of the carbon-containing material particles is selected from the above range, the electric resistance value of the electron-emitting portion 15A formed can be sufficiently decreased, and the mutual adhesion of the carbon-containing material particles can be maintained under a good condition. However, when a mixture of carbon-containing material particles with alumina particles is used as electrically conductive particles, the mutual adhesion of the electrically conductive particles is liable to decrease, so that it is preferred to increase the content of the carbon-containing material particles depending upon the content of the alumina particles. The content of the carbon-containing material particles is particularly preferably 60 % by weight or more. The composition material may contain a dispersing agent for stabilizing the dispersing state of the electrically conductive particles and additives such as a pH adjuster, a desiccant, a curing agent and an antisepatic. There may be used a composition material prepared by coating the electrically conductive particles with a binder to prepare a powder and dispersing the powder in a proper dispersing medium.

[0253] For example, when the crown-shaped electron-emitting portion 15A has a diameter of approximately 1 to 20 μm and when carbon-containing material particles are used as electrically conductive particles, preferably, the particle diameter of the carbon-containing material particles is approximately in the range of from 0.1 μm to 1 μm. When the particle diameter of the carbon-containing material particles is in the above range, an edge portion of the crown-shaped electron-emitting portion 15A is imparted with sufficiently high mechanical strength, and the adhesion of the electron-emitting portion 15A to the cathode electrode 11 comes to be excellent.

[Step-1340]

[0254] Then, as shown in Fig. 28C, the peel layer 51 is removed. The peeling is carried out by immersion in a sodium hydroxide aqueous solution of 2 % by weight for 30 seconds. The peeling may be carried out under supersonic vibration. In this manner. the peel layer 51 and part of the electrically conductive composition layer 52 on the peel layer 51 are together removed, and only that portion of the electrically conductive material layer 52 which is on the exposed cathode electrode 11 in the bottom portion of the opening portion 14 remains. The above remaining portion constitutes the electron-emitting portion 15A. The electron-emitting portion 15A has a surface denting toward the central portion of the opening portion 14 and comes to have the form of a crown. Figs. 29A and 29B schematically show a state after [Step-1340] is finished. Fig. 29B is a schematic perspective view of part of the field emission device, and Fig. 29A is a schematic partial end view taken along line A-A in Fig. 29B. In Fig. 29B, part of the insulating layer 12 and part of the gate electrode 313 are cut out for showing the whole of the electron-emitting portion 15A. It is sufficient to form approximately 5 to 100 electron-emitting portions 15A in one electron-emitting region (overlap region). For reliably exposing the electrically conductive particles on the surface of each electron-emitting portion 15A, a binder exposed on the surface of each electron-emitting portion 15A may be removed by etching.

[Ste-1350]

[0255] Then, the electron-emitting portion 15A is calcined or sintered. The calcining or sintering is carried out in dry atmosphere at 400 °C for 30 minutes. The calcining or sintering temperature can be selected depending upon the binder contained in the composition material. For example, when the binder is an organic material such as water glass, it is sufficient to carry out heat treatment at a temperature at which the inorganic material can be calcined or sintered. When the binder is a thermosetting resin, the heat treatment can be carried out at a temperature at which the thermosetting resin can be cured. For maintaining mutual adhesion of the electrically conductive particles, however, the heat treatment is preferably carried out at a temperature at which the thermosetting resin is neither decomposed to excess nor carbonized. In either case, the heat treatment temperature is required to be a temperature at which neither damage nor a defect is caused on the gate electrode, the cathode electrode and the insulating layer. The heat treatment atmosphere is preferably an inert gas atmosphere for preventing an oxidation from causing an increase in the electric resistivity of the gate electrode and the cathode electrode and for preventing the gate electrode and the cathode electrode from suffering damage or defects. When a thermoplastic resin is used as a binder, no heat treatment may be required in some case.

Example 14

[0256] Fig. 30C shows a schematic partial cross-sectional view of a tlat-type field emission device. The flat-type field emission device comprises a cathode electrode 11 formed on a supporting substrate 10 made, for example, of a glass; an insulating layer 12 formed on the supporting substrate 10 and the cathode electrode 11; a gate electrode 313 formed on the insulating layer 12; an opening portion 14 which penetrates through the gate electrode 313 and is formed in the insulating layer 12; and a flat electron-emitting portion 15B formed on a portion of the cathode electrode 11 which portion is positioned in the bottom portion of the opening portion 14. The electron-emitting portion 15B is formed on the cathode electrode 11 in the form of a stripe extending in the direction perpendicular to the paper surface of Fig. 30C. Further, the gate electrode 313 is extending leftward and rightward on the paper surface of Fig. 30C. The cathode electrode 11 and the gate electrode 313 are composed of chromium (Cr). Specifically, the electron-emitting portion 15B is constituted of a thin layer composed of a graphite powder. A resistance layer 60 composed of SiC is formed between the cathode electrode 11 and the electron-emitting portion 15B for stabilizing the performance of the field emission device and attaining uniform electron emission characteristics. In the flat-type field emission device shown in Fig. 30C, the resistance layer 60 and the electron-emitting portion 15B are formed all over the surface of the cathode electrode 11. However, the present invention shall not be limited to such a structure, and it is sufficient to form the electron-emitting portion 15B at least in the bottom portion of the opening portion 14. The method of producing the flat-type field emission device will be explained hereinafter with reference to Figs. 30A, 30B and 30C showing the schematic partial cross-sectional views of the supporting substrate, etc.

[Step-1400]

[0257] An electrically conductive material layer composed of chromium (Cr) for a cathode electrode is formed on the supporting substrate 10 by a sputtering method and patterned by lithography and a dry etching method, whereby the cathode electrode 11 composed of the electrically conductive material layer in the form of a stripe can be formed on the supporting substrate 10 (see Fig. 30A). The cathode electrode 11 is extending in the direction perpendicular to the paper surface of Fig. 30A.

[Step-1410]

[0258] Then, the electron-emitting portion 15B is formed on the cathode electrode 11. Specifically, the resistance layer 60 composed of SiC is formed on the entire surface by a sputtering method. Then, the electron-emitting portion 15B composed of a graphite powder coating is formed on the resistance layer 60 by a spin coating method and is dried. Then, the electron-emitting portion 15B and the resistance layer 60 are patterned by a known method (see Fig. 30B). The electron-emitting portion 15B is to emit electrons.

[Step-1420]

[0259] Then, the insulating layer 12 is formed on the entire surface. Specifically, the insulating layer 12 composed of SiO_2 is formed on the electron-emitting portion 15B and the supporting substrate 10, for example, by a sputtering method. Alternatively, the insulating layer 12 may be formed by a method in which a glass paste is screen-printed or by a method in which a layer of SiO_2 is formed by a CVD method. Then, the gate electrode 313 in the form of a stripe is formed on the insulating layer 12.

[Step-1430]

[0260] The opening portion 14 is formed through the gate electrode 313 and the insulating layer 12 to expose the electron-emitting portion 15B in the bottom portion of the opening portion 14. Then, heat treatment is carried out at 400 °C for 30 minutes for removing an organic solvent in the electron-emitting portion 15B, whereby the field emission device shown in Fig. 30C can be obtained.

Example 15

[0261] Example 15 is a variant of Example 14. Fig. 31C shows a schematic partial cross-sectional view of the flat-type field emission device in Example 15. The flat-type field emission device shown in Fig. 31C differs from the flat-type field emission device shown in Fig. 30C in the structure of the electron-emitting portion 15B to some extent. The method of producing such a field emission device will be explained below with reference to Figs. 31A, 31B and 31C showing schematic partial cross-sectional views of a supporting substrate, etc.

[Step-1500]

[0262] First, the electrically conductive material layer for a cathode electrode is formed on the supporting substrate 10. Specifically, a resist material layer (not shown) is formed on the entire surface of the supporting substrate 10, and the resist material layer is removed from a portion where the cathode electrode is to be formed. Then, the electrically conductive material layer composed of chromium (Cr) for a cathode electrode is formed on the entire surface by a sputtering method. Further, the resistance layer 60 composed of SiC is formed on the entire surface by a sputtering method, and a graphite powder coating layer is formed on the resistance layer 60 by a spin coating method and is dried. Then, the resist material layer is removed with a peeling solution. In this case, the electrically conductive material layer for a cathode electrode, the resistance layer 60 and the graphite powder coating layer, which are formed on the resist material layer, are also removed. In this manner, a structure in which the cathode electrode 11, the resistance layer 60 and the electron-emitting portion 15B are stacked can be obtained according to a so-called lift-off method (see Fig. 31A).

[Step-1510]

[0263] Then. the insulating layer 12 is formed on the entire surface, and the gate electrode 313 in the form of a stripe is formed on the insulating layer 12 (see Fig. 31B). Then, the opening portion 14 is formed through the gate electrode 313 and the insulating layer 12 to expose the electron-emitting portion 15B in the bottom portion of the opening portion

14 (see Fig. 31C). Electrons are to be emitted from the electron-emitting portion 15B formed on the surface of the cathode electrode 11 which surface is exposed in the bottom portion of the opening portion 14.

Example 16

[0264] Example 16 is a variant of the plane-type field emission device explained in Example 11. The plane-type field emission device of which the schematic partial cross-sectional view is shown in Fig. 32A differs from the plane-type field emission device shown in Fig. 23 in that a fine convexo-concave portion 11A is formed on that surface (corresponding to an electron-emitting portion 15C) of a cathode electrode 211 which is exposed in the bottom portion of the opening portion 14. Such a plane-type field emission device can be produced by the following production method.

[Step-1600]

[0265] First, a cathode electrode 211 (electron-emitting layer) which works as the electron-emitting portion 15C is formed on a supporting substrate 10. Specifically, an electrically conductive material layer composed of tungsten (W) for a cathode electrode is formed on the supporting substrate 10 by a sputtering method, and the electrically conductive material layer for a cathode electrode is patterned by lithography and a dry etching method, whereby the cathode electrode 211 constituted of the electrically conductive material layer for a cathode electrode in the form of a stripe can be formed on the supporting substrate 10.

[Step-1610]

[0266] Then, an insulating layer 12 composed of SiO_2 is formed on the entire surface, specifically, on the supporting substrate 10 and the cathode electrode 211, for example, by a CVD method. The insulating layer 12 may be formed from a glass paste by a screen-printing method. In this case, the opening portion 14 may be concurrently formed.

[Step-1620]

[0267] Then, a gate electrode 313 is formed on the insulating layer 12.

[Step-1630]

[0268] Then, the opening portion 14 is formed in the gate electrode 313 and the insulating layer 12 by lithography and an etching method to expose the cathode electrode 211 in the bottom portion of the opening portion 14. In this manner, the surface of the cathode electrode 211 which surface corresponds to an electron-emitting portion can be exposed in the bottom portion of the opening portion 14. Then, a fine convexo-concave portion 11A is formed on a portion of the cathode electrode which portion is exposed in the bottom portion of the opening portion 14. When the fine convexo-concave portion 11A is formed, and drying etching using SF6 as an etching gas is carried out by an RIE method under a condition where an etching rate of grain boundaries comes to be greater than that of tungsten particles constituting the cathode electrode 211. As a result, the fine convexo-concave portion 11A having dimensions nearly reflecting grain diameters of the tungsten crystals can be formed.

[0269] In the above plane-type field emission device, an intense electric field from the gate electrode 313 is applied to the tine convexo-concave portion 11A of the cathode electrode 211. more specifically to convex portions of the fine convexo-concave portion 11A. In this case, the electric filed applied on the convex portions is intense as compared with a case where the surface of the cathode electrode 211 is flat and smooth, so that electrons are efficiently emitted from the convex portions due to a quantum tunnel effect. It can be therefore expected that the flat-panel display into which the above plane-type field emission devices are incorporated is improved in brightness as compared with the plane-type field emission device having a simply flat and smooth cathode electrode 211 exposed in the bottom portion of the opening portion 14. in the plane-type field emission device shown in Fig. 32A, therefore, a sufficient current density of emitted electrons can be obtained even if the potential difference between the gate electrode 313 and the cathode electrode 211 is relatively small, and a higher brightness of the flat-panel display can be achieved. In other words, the gate voltage required can be decreased if the levels of the brightness are the same, and the power consumption can be lowered.

[0270] In the above-explained embodiment, the opening portion 14 is formed by etching the insulating layer 12 and then the fine convexo-concave portion 11A is formed in the cathode electrode 211 by an anisotropic etching method. However, the fine convexo-concave portion 11A can be also simultaneously formed by the etching which is carried out for forming the opening portion 14. That is, when the insulating layer 12 is etched, an anisotropic etching condition which is expected to have ion-sputtering functions in some extent is employed, and the etching is continued until after

the opening portion 14 having a perpendicular wall is formed, whereby the fine convexo-concave portion 11A can be formed in that portion of the cathode electrode 211 which is exposed in the bottom portion of the opening portion 14. Then, the insulating layer 12 can be isotropically etched.

[0271] In a step similar to [Step-1600], an electrically conductive material layer composed of tungsten for a cathode electrode is formed on the supporting substrate 10 by a sputtering method, and then, the electrically conductive material layer is patterned by lithography and a dry etching method. Then, the fine convexo-concave portion 11A is formed on a surface of the electrically conductive material layer for a cathode electrode, and steps similar to the steps after [Step-1610] are carried out, whereby an field emission device similar to one shown in Fig. 32A can be produced.

[0272] Otherwise, in a step similar to [Step-1600], the electrically conductive material layer composed of tungsten for a cathode electrode is formed on the supporting substrate 10 by a sputtering method, and then, the fine convexo-concave portion 11A is formed in a surface of the electrically conductive material layer for a cathode electrode. Then, the electrically conductive material layer is patterned by lithography and a dry etching method, and steps similar to the steps after [Step-1610] are carried out, whereby an field emission device similar to one shown in Fig. 32A can be produced.

[0273] Fig. 32B shows a variant of the field emission device shown in Fig. 32A. In the field emission device shown in Fig. 32B, the average height position of peaks of the fine convexo-concave portion 11A is present at a level lower than the lower surface of the insulating layer 12 on the supporting substrate side (that is, lowered). For producing such an field emission device, the dry etching in a step similar to [Step-1600] can be continued for a longer period of time. In such a constitution, the electric field intensity near the central portion of the opening portion 14 can be further increased.

[0274] Fig. 33 shows a plane-type field emission device in which a coating layer 11 B is formed on the surface of the cathode electrode 11 corresponding to the electron-emitting portion 15C (more specifically, at least on the fine convexo-concave portion 11A).

[0275] Preferably, the above coating layer 11B is composed of a material having a smaller work function (than a material constituting the cathode electrode 211. The material for the coating layer 11B can be determined depending upon the work function of a material constituting the cathode electrode 211, a potential difference between the gate electrode 313 and the cathode electrode 211 and the current density of emitted electrons to be required. The material for the coating layer IIB includes amorphous diamond. When the coating layer 11B is composed of amorphous diamond, the current density of emitted electrons required for a flat-panel display can be obtained at an electric field of 5×10^7 V/m or less.

[0276] The thickness of the coating layer 11B is determined to such an extent that the coating layer 11B can reflect the fine convexo-concave portion 11A. That is because it is meaningless to form the fine convexo-concave portion 11A if the concave portions of the fine convexo-concave portion 11A are filled with the coating layer 11B to flatten the surface of the electron-emitting portion. Therefore, when. for example, the fine convexo-concave portion 11A is formed while reflecting crystal grain diameters of the electron-emitting portion, the thickness of the coating layer 11B is approximately 30 to 100 nm, although the thickness differs depending upon dimensions of the fine convexo-concave portion 11A. When the average height position of peaks of the fine convexo-concave portion 11A is lowered to a level below the lower surface position of the insulating layer 12, to be exact, it is more preferred to lower the average height position of peaks of the coating layer 11B to a level below the lower surface position of the insulating layer 12.

[0277] Specifically, after [Step-1630], the coating layer 11B composed of amorphous diamond can be formed on the entire surface, for example, by a CVD method. The coating layer 11B is also deposited on an etching mask (not shown) formed on the gate electrode 313 and the insulating layer 12. This deposit portion is removed concurrently with the removal of the etching mask. The coating layer 11B can be formed by a CVD method using, for example, CH_4/H_2 mixed gases or C_O/H_2 mixed gases as a source gas, and the coating layer 11B composed of amorphous diamond is formed by thermal decomposition of the gas containing carbon.

[0278] Otherwise, the field emission device shown in Fig. 33 can be formed as follows. In a step similar to [Step-1600], an electrically conductive material layer composed of tungsten for a cathode electrode is formed on the supporting substrate 10 by a sputtering method, then, the electrically conductive material layer is patterned by lithography and a dry etching method, and then, the fine convexo-concave portion 11A is formed on a surface of the electrically conductive material layer. Then, the coating layer 11B is formed, and then, procedures after [Step-1610] are carried out.

[0279] Otherwise, the field emission device shown in Fig. 33 can be produced as follows. In a step similar to [Step-1600], an electrically conductive material layer composed of tungsten for a cathode electrode is formed on the supporting substrate 10 by a sputtering method, then, the fine convexo-concave portion 11A is formed on a surface of the electrically conductive material layer, and then, the coating layer 11B is formed. Then, the coating layer 11B and the electrically conductive material layer are patterned by lithography and a dry etching method, and procedures after [Step-1610] are carried out.

[0280] Otherwise, the material for the coating layer can be selected from materials which have a larger secondary electron gain δ than an electrically conductive material which is to constitute the cathode electrode.

[0281] A coating layer may be formed on the electron-emitting portion 15C (on the surface of the cathode electrode 211) of the plane-type field emission device shown in Fig. 23. In this case, after [Step-1120], the coating layer 11B can be formed on the surface of the cathode electrode 211 which surface is exposed in the bottom portion of the opening portion 14. Otherwise, in [Step-1100], for example, an electrically conductive material layer for a cathode electrode is formed on the supporting substrate 10, the coating layer 11B is formed on the electrically conductive material layer, and these layers are patterned by lithography and a dry etching method.

Example 17

[0282] Fig. 37B shows a schematic partial cross-sectional view of the crater-type field emission device. In the crater-type field emission device, a cathode electrode 411 having a plurality of projection portions 411A for emitting electrons and concave portions 411B each of which is surrounded by the projection portion 411A is provided on the supporting substrate 10. Fig. 36B shows a schematic perspective view of the crater-type field emission device from which an insulating layer 12 and a gate electrode 313 are removed.

[0283] While the form of each concave portion is not specially limited, each concave portion has a nearly spherical surface, which is related to the following fact. In the production of the above crater-type field emission device. spheres are used, and part of each sphere is reflected when each concave portion 411B is formed. When each concave portion 411B has a nearly spherical surface, the projection portion 411A surrounding the concave portion 411B is ringed or circular, and in this case, the concave portion 411B and the projection portion 411A as a whole have a crater-like or caldera-like form. The projection portion 411A is for emitting electrons, so that a top end portion 411C of each particularly preferably is sharp in view of improving electron emission efficiency. The profile of top end portion 411C of each projection portion 411 A may have an irregular convexo-concave form or may be flat. The layout of the projection portions 411 A per pixel may be regular or at random. Each concave portion 411B may be surrounded by the projection portion 411A continued along the circumferential direction of the concave portion 411 A, and in some cases, each concave portion 411B may be surrounded by the projection portion 411A discontinuous along the circumferential direction of the concave portion 411B.

[0284] In the method of producing the above crater-type field emission device, more specifically, the step of forming the cathode electrode in the form of a stripe on the supporting substrate comprises the steps of forming an electrically conductive material layer for a cathode electrode in the form of a stripe on the supporting substrate, such that the electrically conductive material layer covers a plurality of spheres; and removing the spheres to remove a portion of the electrically conductive material layer for a cathode electrode which portion covers the sphere and thereby forming a cathode electrode having a plurality of projection portions for emitting electrons and concave portions each of which is surrounded by the projection portion and reflects part of the sphere.

[0285] Preferably, the spheres are removed by state change and/or chemical change of the spheres. The state change and/or chemical change of the sphere includes changes such as expansion, sublimation, foaming, gas generation, decomposition, combustion and carbonization and combinations of these. For example, when the spheres are composed of an organic material, more preferably, the spheres are removed by combustion. The removal of the spheres and the removal of portion of the electrically conductive material layer for a cathode electrode which portion covers the sphere are not necessarily required to take place concurrently, or the removal of the spheres and the removal of portions of the electrically conductive material layer for a cathode electrode, the insulating layer and the gate-electrode-constituting layer which portions cover the sphere are not necessarily required to take place concurrently. For example, when part of the spheres remain after the portion of the electrically conductive material layer for a cathode electrode which portion covers the sphere or when the above portion and the portions of the insulating layer and the gate-electrode-constituting layer are removed, the remaining spheres can be removed later.

[0286] In particular, when the spheres are composed of an organic material and when the spheres are combusted, for example, carbon monoxide, carbon dioxide and vapor steam are generated to increase a pressure in a closed space near the sphere, and the electrically conductive material layer for a cathode electrode near the sphere bursts when a pressure durability limit is exceeded. The portion of the electrically conductive material layer for a cathode electrode which portion covers the sphere is dissipated by the force of the burst, to form the projection portion and the concave portion, and the sphere is also removed. Otherwise, when the spheres are, for example, combusted, the electrically conductive material layer for a cathode electrode, the insulating layer and the gate-electrode-constituting layer burst according to a similar mechanism when a pressure durability limit is exceeded. Portions of the electrically conductive material layer for a cathode electrode, the insulating layer and the gate-electrode-constituting layer are dissipated by the force of the burst, to form the projection portion and the concave portion and to form the opening portion at the same time, and the sphere is also removed. That is, no opening portion exists in the insulating layer and the gate-electrode-constituting layer before the removal of the spheres, and the opening portion is formed together with the removal of the sphere. In this case, the initial process of combustion proceeds in a closed space, so that part of the spheres may be carbonized. Preferably, the thickness of portion of the electrically conductive material layer for

a cathode electrode which portion covers the sphere is decreased to such an extent that said portion can be dissipated by the burst. Otherwise, preferably, the thickness of each of portions of the electrically conductive material layer for a cathode electrode, the insulating layer and the gate-electrode-constituting layer which portions cover the sphere is decreased to such an extent that said portions can be dissipated by the burst. In the insulating layer, particularly preferably, its portion covering no spheres has a thickness nearly equal to a diameter of each sphere.

[0287] In an field emission device in Example 19 to be described later, the spheres can be removed by state change and/or chemical change of the spheres. Since, however, the bursting of the electrically conductive material layer for a cathode electrode is not involved, the spheres can be easily removed by exerting an external force in some cases. In an field emission device in Example 20 to be described later, the opening portion is formed prior to the removal of the sphere. When the opening portion has a larger diameter than the sphere, the sphere can be removed with an external force. The external force includes physical forces such as a pressure caused by blowing with air or an inert gas, a pressure caused by blowing a wash liquid, a magnetic suction force, an electrostatic force and a centrifugal force. Unlike the field emission device of Example 17, in the field emission device of Example 19 or 20, it is not required to dissipate the portion of the electrically conductive material layer for a cathode electrode which covers the sphere, or, in some cases, it is not required to dissipate the above portion, and portions of the insulating layer and the gate-electrode-constituting layer, so that there is an advantage that no residue arises from the electrically conductive material layer for a cathode electrode, the insulating layer or the gate-electrode-constituting layer.

[0288] In the field emission device of Example 19 or 20 to be described later, preferably. at least the surface of the sphere used therefor is composed of a material having a larger interfacial tension (surface tension) than material constituting the electrically conductive material layer for a cathode electrode, or in some cases, than materials constituting the above electrically conductive material layer, the insulating layer and the gate-electrode-constituting layer. In the field emission device of Example 20, the electrically conductive material layer for a cathode electrode, the insulating layer and the gate-electrode-constituting layer thereby do not cover at least top portions of the spheres. and there can be obtained a state where the opening portion is formed in the insulating layer and the gate-electrode-constituting layer from the beginning. The diameter of the opening portion differs depending, for example, upon a relationship between the thickness of a material for each of the electrically conductive material layer for a cathode electrode, the insulating layer and the gate-electrode-constituting layer and the diameter of each sphere; methods of forming the electrically conductive material layer for a cathode electrode, the insulating layer and the gate-electrode-constituting layer; and the interfacial tension (surface tension) of a material for each of the electrically conductive material layer for a cathode electrode, the insulating layer and the gate-electrode-constituting layer.

[0289] In the field emission device of Examples 19 or 20 to be described later. it is sufficient that the spheres have the surfaces which satisfy the above condition concerning the interfacial tension. That is, the portion having a larger interfacial tension than any one of the electrically conductive material layer for a cathode electrode, the insulating layer and the gate-electrode-constituting layer may be only a surface of the sphere or may be the entirety of the sphere. The material for the surface and/or the entirety of the sphere may be an inorganic material, an organic material or a combination of an inorganic material with an organic material. In the field emission device of Example 19 or 20, when the electrically conductive material layer for a cathode electrode is composed of a general metal material and when the insulating layer is composed of a silicon oxide material such as glass, generally, a highly hydrophilic state is formed since hydroxyl groups derived from adsorbed water are present on the metal material and since dangling bonds of Si-O bonds and hydroxyl group derived from adsorbed water are present on the surface of the insulating layer. It is therefore particularly effective to spheres having hydrophobic surface-treatment layers. The material for the hydrophobic surface-treatment layer includes fluorine resins such as polytetrafluoroethylene. When the sphere has a hydrophobic surface-treatment layer, and, if a portion inside the hydrophobic surface-treatment layer is considered a core, the material for the core may be glass, ceramic or a polymer material other than the fluorine resin.

[0290] Although not specially limited, the organic material for the sphere is preferably a general-purpose polymer material. When the polymer material has an extremely high polymerization degree or has an extremely large content of double and triple bonds, too high a combustion temperature is required, and when the spheres are removed by combustion, a detrimental effect may be caused on the electrically conductive material layer for a cathode electrode, the insulating layer and the gate-electrode-constituting layer. It is therefore preferred to select a polymer material which is combustible or carbonizable at a temperature at which no detrimental effect is caused on the above layers. When the insulating layer is composed of a material which requires combustion at a post step, such as a glass paste, it is preferred to select a polymer material which is combustible or carbonizable at a calcining or sintering temperature of the glass paste, in order to decrease the number of the manufacturing steps. Since a glass paste has a typical calcining temperature of approximately 530 °C, the combustion temperature of the polymer material is preferably approximately 350 to 500 °C. Typical examples of the polymer material include styrene, urethane, acryl, vinyl, divinylbenzene, melamine, formaldehyde and polymethylene homopolymers or copolymers. For securing a reliable layout on the supporting substrate, there may be used fixable spheres capable of adhering. As fixable spheres, spheres composed of an acryl resin are used.

[0291] Otherwise, thermally expandable microspheres having a vinylidene chloride-acrylonitrile copolymer as outer shells and encapsulating isobutane as a foaming agent can be used as spheres. In the field emission device of Example 17, for example, the above thermally expandable microspheres are employed and heated. In this case, a polymer constituting the outer shells is softened, and the encapsulated isobutane is gasified to undergo expansion. As a result, there are formed hollow true spheres having a diameter approximately 4 times as large as a diameter found before the expansion. As a result, in the field emission device of Example 17, the projection portions for emitting electrons and the concave portions each of which is surrounded by the projection portion and reflects part of form of the sphere can be formed in the electrically conductive material layer for a cathode electrode. In addition to the above concave portions and the above projection portions, further, the opening portions can be also formed in the gate-electrode-constituting layer and the insulating layer. In the present specification, the expansion of thermally expandable microspheres is also included in the concept of the removal of the sphere. Then, thermally expandable microspheres can be removed with a proper solvent.

[0292] In the field emission device of Example 17, the electrically conductive material layer for a cathode electrode which layer covers the spheres can be formed after a plurality of the spheres are arranged on the supporting substrate. In this case or in the field emission device of Example 19 or 20 to be described later, the method of arranging a plurality of the spheres includes a dry method in which the spheres are sprayed onto the supporting substrate. For spraying the spheres, there can be applied a method in which spacers are sprayed for maintaining a panel distance at a constant distance in the field of producing liquid crystal display devices. Specifically, a so-called spray gun for ejecting the spheres through a nozzle with a compressed gas can be used. When the spheres are ejected through the nozzle, the spheres may be in a state in which they are dispersed in a volatile solvent. Otherwise, the spheres can be sprayed by means of an apparatus or a method which is generally used in the field of an electrostatic powder application or coating. For example, the spheres negatively charged can be sprayed to the supporting substrate grounded, with an electrostatic spray gun, using a corona discharge. Since the spheres used are very small as will be described later, the spheres sprayed onto the supporting substrate adhere to the surface of the supporting substrate, for example, with an electrostatic force, and the adhering spheres do not easily fall off from the supporting substrate. When the spheres are pressed after a plurality of the spheres are arranged on the supporting substrate, overlapping of a plurality of the spheres on the supporting substrate can be overcome, and the spheres can be densely arranged on the supporting substrate so as to form a single layer so as to arrange one sphere and another sphere side by side.

[0293] Otherwise, there may be employed a constitution in which, like the field emission device of Example 18 to be described later, a composition layer composed of a dispersion of the spheres and a cathode electrode material in a dispersing agent is formed on the supporting substrate, thereby to arrange a plurality of the spheres on the supporting substrate and to cover each sphere with the cathode electrode composed of the cathode electrode material, and thereafter, the dispersing agent is removed. The composition can have the property of a slurry or paste, and the component and viscosity of the slurry or paste can be selected as required depending upon the above properties be desired. Typically, the cathode electrode material is preferably formed of fine particles having a lower precipitation rate than the sphere in the dispersing agent. The material for the above fine particles includes carbon, barium, strontium and iron. After the dispersing agent is removed, the cathode electrode is calcined or sintered as required. The method of forming the composition layer on the supporting substrate includes a spraying method, a dropping method, a spin coating method and a screen-printing method. When the spheres are arranged, each sphere is concurrently covered (coated) with the electrically conductive material layer for a cathode electrode, which material is the cathode electrode material. In some method of forming the above composition layer, it is required to pattern the electrically conductive material layer for a cathode electrode.

[0294] In the field emission device of Example 19 or 20 to be described later, there may be employed a constitution in which a composition layer composed of a dispersion of the spheres in a dispersing agent is formed on the supporting substrate, thereby to arrange a plurality of the spheres on the supporting substrate, and then the dispersing agent is removed. The composition can have the property of a slurry or paste, and the component and viscosity of the slurry or paste can be selected as required depending upon the above properties to be desired. Typically, an organic solvent such as isopropyl alcohol is used as a dispersing agent, and the dispersing agent can be removed by volatilization. The method of forming the composition layer on the supporting substrate includes a spraying method, a dropping method, a spin coating method and a screen-printing method.

[0295] The gate-electrode-constituting layer and the electrically conductive material layer for a cathode electrode extend in directions different from each other (for example, a projection image of the gate-electrode-constituting layer in the form of a stripe and the electrically conductive material layer for a cathode electrode in the form of a stripe make an angle of 90°), and for example, they are patterned in the form of stripes. Electrons are emitted from the projection portions positioned in the electron-emitting region. It is therefore functionally sufficient that the projection portions are present in the electron-emitting region alone. Even if the projection portions and the concave portions exist in a region different from the electron-emitting region, however, such projection portions and concave portions remain covered with the insulating layer and do not work to emit electrons. It is therefore no problem if the spheres are arranged in the

entire surface.

[0296] In contrast, when portions of the electrically conductive material layer for a cathode electrode, the insulating layer and the gate-electrode-constituting layer which portions cover the sphere are removed, arrangement positions of individual spheres and formation positions of the opening portions have one-to-one correspondence, so that the opening portions are formed in a region different from the electron-emitting region. The opening portion formed in a region different from the electron-emitting region will be referred to as "ineffective opening portion" and distinguished from the original opening portion which works for electron emission. Meanwhile, even if ineffective opening portions are formed in a region other than the electron-emitting region, the ineffective opening portions do not at all work as field emission devices, nor do they cause any detrimental effect on the performance of the field emission devices formed in the electron-emitting region. The reason therefor is as follows. Even if the projection portion and the concave portion are exposed in the bottom portion of the ineffective opening portion, no gate electrode is formed on the upper end portion of the ineffective opening portion. Otherwise, even if the gate electrode is formed in the upper end portion of the ineffective opening portion, neither the projection portion nor the concave portion is exposed in the bottom portion; or neither the projection portion nor the concave portion is exposed in the bottom portion of the ineffective opening portion and no gate electrode is formed in the upper end portion and the surface of the supporting substrate is merely exposed. It is therefore no problem even if the spheres are arranged in the entire surface. A hole formed in a boundary between the electron-emitting region and other region is included in the opening portion.

[0297] The diameter of the sphere can be selected depending upon the diameter of a desired opening portion, the diameter of the concave portion, display screen dimensions of a flat-panel display constituted using the field emission devices, the number of pixels, dimensions of the electron-emitting region (overlapped region) and the number of the field emission devices per pixel. The diameter of the sphere is preferably in the range of from 0.1 to 10 μm. For example, spheres commercially available as spacers for liquid crystal display devices are preferred since they have a particle diameter distribution of 1 to 3 %. While the form of the sphere is ideally truly spherical, it is not necessarily required to be truly spherical. In some method of producing the field emission devices, opening portions or ineffective opening portions can be formed in portions where the spheres are arranged, and it is preferred to arrange the spheres in a density of approximately 100 to 5000 spheres/mm^2. For example, when the spheres are arranged in the supporting substrate in a density of approximately 1000 spheres/mm^2, and for example, if the electron-emitting region has dimensions of 0.5 mm x 0.2 mm, approximately 100 spheres are present in the electron-emitting region, and approximately 100 projection portions are formed. When the projection portions approximately in such a number are formed per electron-emitting region, the fluctuation of diameters of the concave portions, caused by the fluctuation in the particle diameter distribution and the sphericity of the spheres, is nearly averaged, and the current density of emitted electrons per pixel (or per subpixel) and the brightness come to be uniform.

[0298] In the field emission device of Example 17 or any one of Examples 18 to 20, part of the form of the sphere is reflected in the form of concave portion constituting the electron-emitting portion. The profile of top end portion of each projection portion may have an irregular convexo-concave form or may be flat. In the field emission device of Example 17 or 18, in particular, the above top end portion is formed by fracture or burst of the electrically conductive material layer for a cathode electrode, so that the top end portion of each projection portion is liable to have an irregular form. When the top end portion is sharpened by fracture or burst, advantageously, the top end portion can function as a highly efficient electron-emitting portion. In the field emission device of any one of Examples 17 to 20, the projection portion surrounding the concave portion comes to be ringed or circular, and in this case. the concave portion and the projection portion as a whole have the form of crater or caldera.

[0299] The layout of the projection portions on the supporting substrate may be regular or at random, and depends upon the method of arranging the spheres. When the above dry method or a wet method is employed, the layout of the projection portions on the supporting substrate comes to be at random. In the field emission device of any one of Examples 17 to 20, when the opening portion is formed in the insulating layer after the formation of the insulating layer, there may be employed a constitution in which a protective layer is formed for avoiding damage of top end portions of the projection portions after the formation of the projection portions, and the protective layer is removed after the opening portion is formed. The material for the protective layer includes chromium.

[0300] The method of producing the field emission device of Example 17 will be explained with reference to Figs. 34A, 34B, 35A, 35B, 36A, 36B, 37A and 37B. Fig. 34A, Fig. 35A and Fig. 36A are schematic partial end views, Figs. 37A and 37B are schematic partial cross-sectional views, and Fig. 34B, 35B and 36B are schematic partial perspective views showing wider ranges than those in Figs. 34A, 35A and 36A.

[Step-1700]

[0301] First, a cathode electrode 411 covering a plurality of spheres 80 is formed on the supporting substrate 10. Specifically, the spheres 80 are arranged on the entire surface of the supporting substrate 10 made, for example, of glass. The spheres 80 are composed, for example, of a polymethylene-based polymer material, and they have an

average particle diameter of approximately 5 μm and a particle diameter distribution of less than 1 %. The spheres 80 are arranged on the supporting substrate 10 at random at a density of approximately 1000 spheres/mm^2 with a spray gun. The method of spraying the spheres with a spray gun includes a method of spraying a mixture of the sphere with a volatile solvent and a method of ejecting the spheres in a powder state from a nozzle. The arranged spheres 80 are held on the supporting substrate 10 by an electrostatic force. Figs. 34A and 34B shows such a state.

[Step-1710]

[0302] An electrically conductive material layer 411' for a cathode electrode is formed on the spheres 80 and the supporting substrate 10. Figs. 35A and 35B show a state where the electrically conductive material layer 411' for a cathode electrode is formed. The electrically conductive material layer 411' for a cathode electrode can be formed, for example, by screen-printing a carbon paste in the form of a stripe. In this case, the spheres 80 are arranged on the entire surface of the supporting substrate 10, so that some of the spheres 80 are naturally not covered with the electrically conductive material layer 411' as shown in Fig. 35B. Then, the electrically conductive material layer 411' is dried, for example, at 150 °C for removing water and a solvent contained in the electrically conductive material layer 411' and flattening the electrically conductive material layer 411'. At this temperature, the spheres 80 undergo any state change and/or chemical change. The above screen-printing using a carbon paste may be replaced with a method in which the electrically conductive material layer 411' for a cathode electrode is formed on the entire surface and the electrically conductive material layer 411' is patterned by general lithography and a general dry etching method to form the electrically conductive material layer 411' for a cathode electrode in the form of a stripe. When the lithography is applied, generally, a resist layer is formed by a spin coating method. In the spinning, if the number of spinning of the supporting substrate 10 is 500 rpm and if the spinning time period is approximately several seconds long, the spheres 80 are held on the supporting substrate 10 without dropping off or shifting in position.

[Step-1720]

[0303] Portions of the electrically conductive material layer 411' for a cathode electrode which portions cover the spheres 80 are removed by removing the spheres 80. whereby there is formed a cathode electrode 41 having projection portions 411A and concave portions 411B each of which is surrounded by the projection portion 411A and reflects part of form of each sphere 80. Figs. 36A and 36B shows the thus-obtained state. Specifically, the spheres 80 are combusted by heating around 530 °C while the electrically conductive material layer 411' for a cathode electrode is also calcined or sintered. The pressure in each closed space near each sphere 80 increases together with the combustion of the sphere 80, and a portion of the electrically conductive material layer 411' which portion covers the sphere 80 bursts when a certain pressure durability limit is exceeded, and such a portion is removed. As a result, the projection portions 411A and the concave portions 411B are formed in part of the cathode electrode 411 formed on the supporting substrate 10. When some portions of the sphere remain as a residue after the removal of the spheres, the residue can be removed with a proper wash liquid depending upon a material constituting the spheres used.

[Step-1730]

[0304] Then, the insulating layer 12 is formed on the cathode electrode 411 and the supporting substrate 10. Specifically, for example, a glass paste is screen-printed on the entire surface to form a layer having a thickness of approximately 5 μm. Then, the insulating layer 12 is dried, for example, at 150 °C to remove water and a solvent contained the insulating layer 12 and to flatten the insulating layer 12. The above screen-printing using a glass paste may be replaced, for example, with the formation of an SiO_2 layer by a plasma CVD method.

[Step-1740]

[0305] Then, the gate electrode 313 in the form of a stripe is formed on the insulating layer 12 (see Fig. 37A). The extending direction of a projection image of the gate-electrode-constituting layer in the form of a stripe makes an angle of 90° with the extending direction of a projection image of the electrically conductive material layer for a cathode electrode in the form of a stripe.

[Step-1750]

[0306] Then, in the electron-emitting region where the projection image of the gate electrode 313 and the projection image of the cathode electrode 411 overlap, the opening portion 14 are formed through the gate electrode 313 and the insulating layer 12, thereby to expose a plurality of the projection portions 41IA and the concave portions 411B in

the bottom portion of the opening portion 14. The opening portion 14 can be obtained by forming a resist mask according to general lithography and etching through the resist mask. Preferably, the etching is carried out under a condition sufficiently high etching selectivity to the cathode electrode 411 is secured. Otherwise, after the formation of the projection portions 411A, preferably, a protective layer composed of chromium is formed in advance, and after the opening portion 14 is formed, the protective layer is removed. Then, the resist mask is removed. In this manner, the field emission device shown in Fig. 37B can be obtained.

[0307] As a variant of the method of producing the field emission device of Example 17, there may be employed a constitution in which [Step-1730] to [Step-1750] are carried out after [Step-1710] and then [Step-1720] is carried out. In this case, the combustion of the spheres and the calcining or sintering of the material for an insulating layer 12 can be carried out concurrently.

[0308] Otherwise, [Step-1730] is carried out after [Step-1710], and in a step similar to [Step-1740], further, a gate-electrode-constituting layer free of the opening portion in the form of a stripe is formed on the insulating layer. Then, [Step-1720] is carried out. In this manner, portions of the electrically conductive material layer 411' for a cathode electrode . the insulating layer 12 and the gate-electrode-constituting layer which portions cover the spheres 80 are removed, whereby the opening portion can be formed in the gate electrode 313 and the insulating layer 12 and the electron-emitting portion having the projection portion 411A and the concave portion 411 B which is surrounded by the projection portion 411A and reflects part of the form of each sphere 80 can be formed in the cathode electrode 411 which is positioned in the bottom portion of the opening portion. That is, the pressure in each closed space near each sphere 80 increases together with the combustion of the sphere 80, and portions of the electrically conductive material layer 411' for a cathode electrode, the insulating layer 12 and the gate-electrode-constituting layer which portions cover the sphere are burst when a certain pressure durability limit is exceeded, and the opening portion is formed together with the projection portion 411A and the concave portion 411B. Further, the sphere 80 is removed. The opening portion is formed in the gate electrode 313 and the insulating layer 12 and reflects part of the sphere 80. In the bottom portion of the opening portion, there remains the projection portion 411A for emitting electrons and the concave portion 411B which is surrounded by the projection portion 411A and reflects part of the form of the sphere.

Example 18

[0309] Example 18 is a variant of Example 17. The method of producing a crater-type field emission device of Example 18 will be explained with reference to Figs. 38A, 38B and 38C. The method of Example 18 differs from the method of Example 17 in that the step of arranging a plurality of the spheres 80 on the supporting substrate 10 includes the steps of forming a composition layer 81 composed of a composition which is a dispersion of the spheres 80 and the cathode electrode material in a dispersing agent on the supporting substrate 10, thereby to arrange a plurality of the spheres on the supporting substrate 10, covering the spheres 80 with the cathode electrode 411 composed of the cathode electrode material, and then, removing the dispersing agent, that is, the above step is a wet method.

[Step-1800]

[0310] First, a plurality of the spheres are arranged on the supporting substrate 10. Specifically, the composition layer 81 composed of a composition which is a dispersion of the spheres 80 and the cathode electrode material 81B in a dispersing agent layer 81A is formed on the supporting substrate 10. That is, for example, isopropyl alcohol is used as a dispersing agent, and a composition is prepared by dispersing the spheres 80 which are composed of a polymethylene polymer material and have an average particle diameter of approximately 5 μm and carbon particles having an average particle diameter of 0.05 μm as the cathode electrode material 81B in the dispersing agent 81A. The composition is screen-printed on the supporting substrate 10 in the form of a stripe, to form the composition layer 81. Fig. 38A shows a state found immediately after the formation of the composition layer 81.

[Step-1810]

[0311] In the composition layer 81 held on the supporting substrate 10, the spheres 80 precipitates soon to be arranged on the supporting substrate 10 and the cathode electrode material 81B also precipitates to form an electrically conductive material layer 411' (composed of the cathode electrode material 81B) for a cathode electrode, whereby a plurality of the spheres 80 can be arranged on the supporting substrate 10 and the spheres 80 can be covered with the electrically conductive material layer 411' (composed of the cathode electrode material 81B) for a cathode electrode. Fig. 38B shows the thus-obtained state.

[Step-1820]

[0312] Then, the dispersing agent 81A is removed by volatilization. Fig. 38C shows the thus-obtained state.

[Step-1830]

[0313] Then, steps similar to [Step-1720] to [Step-1750] in Example 17 or variants of the method of producing the field emission device of Example 17 is carried out, whereby an field emission device similar to the device shown in Fig. 37B can be completed.

Example 19

[0314] Example 19 is also a variant of Example 17. In the method of producing a crater-type field emission device in Example 19, more specifically, the step of forming the cathode electrode in the form of a stripe on the supporting substrate comprises the steps of arranging a plurality of the spheres on the supporting substrate; forming a cathode electrode which has a plurality of the projection portions for emitting electrons and the concave portions each of which is surrounded by the projection portion and reflects part of the sphere, on the supporting substrate; and removing the spheres. The spheres are arranged on the supporting substrate by spraying. The spheres have a hydrophobic surface-treatment layer. The method of producing such an field emission device will be explained with reference to Figs. 39A, 39B and 39C hereinafter.

[Step-1900]

[0315] First, spheres 180 are arranged on the supporting substrate 10.

[0316] Specifically, a plurality of the spheres 180 are arranged on the supporting substrate 10 made, for example, of glass. The spheres 180 are formed by providing a core material 180A composed, for example, of a divinylbenzene polymer material and coating the core material 180A with a surface-treatment layer 180B composed of a polytetrafluoroethylene resin, and the spheres 180 have an average diameter of approximately 5 μm and a particle diameter distribution of less than 1 %. The spheres 180 are arranged on the supporting substrate 10 in a density of approximately 1000 spheres/mm^2 at random with a spray gun. The arranged spheres 180 are held on the supporting substrate 10 by an electrostatic force. Fig. 39A shows the thus-obtained state.

[Step-1910]

[0317] Then, on the supporting substrate 10 is formed a cathode electrode 411 (constituted of an electrically conductive material layer for a cathode electrode) having projection portions 411A and concave portion 411B each of which is surrounded by the projection portion 411A and reflects part of form of the sphere 180, the projection portions 411A being formed around the spheres 180. Specifically, as described with regard to the field emission device in Example 17, for example, a paste is screen-printed in the form of a stripe. In the field emission device in Example 19, the surface of each sphere 180 has hydrophobic nature due to the surface-treatment layer 180B, so that the paste screen-printed on the sphere 180 is immediately repelled and dropped off and is deposited around the sphere 180 to form the projection portion 411 A. The top end of each projection portion 411A is not so sharpened as that in the field emission device in Example 17. A portion of the electrically conductive material layer for a cathode electrode which portion enters between the sphere 180 and the supporting substrate 10 constitutes the concave portion 411B. While Fig. 39B shows a state where a gap is present between the cathode electrode 411 and the sphere 180, the cathode electrode 411 and the sphere 180 are in contact with each other in some cases. Then, the cathode electrode 411 is dried, for example, at 150 (C. Fig. 39B shows the thus-obtained state.

[0318] Then, an external force is exerted on the spheres 180 to remove the spheres 180 from the supporting substrate 10. Specifically, the method of removal includes a washing method and a method of blowing a compressed gas. Fig. 39C shows the thus-obtained state. The spheres can be also removed by the state change/chemical change of the spheres, more specifically, for example, by combustion, which is also applicable to the field emission device in Example 20 to be described below.

[Step-1930]

[0319] Then, [Step-1730] to [Step-1750] for the field emission device in Example 17 are carried out, whereby there can be obtained an field emission device which is almost the same as the device shown in Fig. 37B.

[0320] In a variant of the method of producing the field emission device in Example 19, there may be employed a

constitution in which [Step-1730] to [Step-1750] for the field emission device in Example 17 are carried out after [Step-1910] and then [Step-1920] is carried out.

Example 20

[0321] In the method of producing a crater-type field emission device in Example 20, more specifically, the step of forming the cathode electrode in the form of a stripe on the supporting substrate comprises the steps of arranging a plurality of the spheres on the supporting substrate; and forming a cathode electrode which has a plurality of the projection portions for emitting electrons and the concave portions each of which is surrounded by the projection portion and reflects part of the sphere, on the supporting substrate, each projection portion being formed in a circumference of each sphere. When an insulating layer is formed on the entire surface, the insulating layer having opening portions above the spheres is formed on the cathode electrode and the supporting substrate. The spheres are removed after the opening portions are formed. In the method of producing the field emission device in Example 20, a plurality of the spheres are arranged on the supporting substrate by spraying the spheres. Each sphere has a hydrophobic surface-treatment layer. The method of producing the field emission device in Example 20 will be explained with reference to Figs. 40A, 40B, 41A and 41B.

[Step-2000]

[0322] First, a plurality of the spheres 180 are arranged on the supporting substrate 10. Specifically, a step similar to the [Step-1900] in Example 19 is carried out.

[Step-2010]

[0323] Then, formed on the supporting substrate 10 is a cathode electrode 411 having a plurality of projection portions 411A for emitting electrons and concave portions each of which is surrounded by the projection portion 411A and reflects part of the form of the sphere 180, each projection portion 411A being formed in a circumference of each sphere 180. Specifically, a step similar to [Step-1910] in Example 19 is carried out.

[Step-2020]

[0324] An insulating layer 12 having opening portions 14A above the spheres is formed on the cathode electrode 411 and the supporting substrate 10. Specifically, a glass paste is screen-printed on the entire surface to form a layer having a thickness of approximately 5 μm. The screen-printing of a glass paste can be carried out in the same manner as in the field emission device of Example 17. The surface of each sphere 180 has hydrophobic nature due to the surface-treatment layer 180B, so that the screen-printed glass paste is immediately repelled and dropped off and that a portion of the insulating layer 12 which portion is on each sphere 180 shrinks due to its surface tension. As a result, the top portion of each sphere 180 is exposed into the opening portion 14A without being covered with the insulating layer 12. Fig. 40A shows the thus-obtained state. In a shown embodiment, the top end portion of the opening portion 14A has a larger diameter than the sphere 180. When the surface-treatment layer 180B has a smaller interfacial tension (surface tension) than the glass paste, the opening portion 14A tends to have a smaller diameter. When the surface-treatment layer 180B has an extremely larger interfacial tension than the glass paste, the opening portion 14A tends to have a larger diameter. Then, the insulating layer 12 is dried, for example, at 150 °C.

[Step-2050]

[0325] Then, a gate electrode 313 having an opening portion 14B communicating with the opening portion 14A is formed on the insulating layer 12. Specifically, a paste is screen-printed in the form of a stripe. The screen-printing of a paste can be carried out in the same manner as in the field emission device of Example 17. Since, however, the surface of the sphere 180 has higher hydrophobic nature due to the surface-treatment layer 180B, the paste screen-printed on the sphere 180 is immediately repelled and shrinks due to its own surface tension to form a state where it adheres only to the surface of the insulating layer 12. In this case, the gate electrode 313 may be formed so as to droop from the opening end portion of the insulating layer 12 into the opening portion 14A to some extent. Then, the gate electrode 313 is dried, for example, at 150 °C. Fig. 40B shows the thus-completed state. When the surface-treatment layer 180B has a smaller interfacial tension than the paste, the opening portion 14A tends to have a smaller diameter. When the surface-treatment layer 180B has an extremely larger interfacial tension than the paste, the opening portion 14A tends to have a larger diameter.

[Step-2040]

[0326] Then, the sphere 180 exposed in the opening portion 14A and 14B is removed. Specifically, the sphere 18 is combusted by heating the sphere at approximately 530 °C. a typical temperature for calcining or sintering a glass paste, which heating also works to calcine or sinter the cathode electrode 411 and the insulating layer 12. In this case, the insulating layer 12 and the gate electrode 313 have the opening portions 14A and 14B from the beginning unlike the field emission device in Example 17, so that part of the cathode electrode 411, the insulating layer 12 or the gate electrode 313 is not dissipated in any case, and the sphere 180 is readily removed. When the upper end portion of the opening portions 14A and 14B has a larger diameter than the sphere 180, the sphere can be removed by an external force such as washing or blowing of a compressed gas without combusting the sphere 180. Fig. 41A shows the thus-completed state.

[Step-2050]

[0327] Part of the insulating layer 12 which part corresponds to the side wall surface of the opening portion 14 is isotropically etched, whereby an field emission device shown in Fig. 41B can be completed. In this embodiment, the lower end of the gate electrode 313 faces downward, which is preferred for increasing the electric field intensity in the opening portion 14.

Example 21

[0328] Fig. 42A shows a schematic partial cross-sectional view of an edge-type field emission device. The edge-type field emission device has a cathode electrode (electron-emitting layer) 111 formed on the supporting substrate 10 in the form of a stripe; an insulating layer 12 formed on the supporting substrate 10 and the cathode electrode 111; and a gate electrode 313 formed on the insulating layer 12 in the form of a stripe. An opening portion 14 is formed through the gate electrode 313 and the insulating layer 12. An edge portion 111A of the cathode electrode 111 is exposed in the bottom portion of the opening portion 14. A voltage is applied to the cathode electrode 111 and the gate electrode 313, whereby electrons are emitted from the edge portion 111A of the cathode electrode 111.

[0329] As shown in Fig. 42B, a concave portion 10A may be formed in the supporting substrate 10 below the cathode electrode 111 inside the opening portion 14. Otherwise, as Fig. 42C shows a schematic partial cross-sectional view, the edge-type field emission device may have a first gate electrode 13A formed on the supporting substrate 10; a lower insulating layer 12A formed on the supporting substrate 10 and the first gate electrode 13A; a cathode electrode 111 formed on the lower insulating layer 12A; an upper insulating layer 12B formed on the lower insulating layer 12A and the cathode electrode 111; and a second gate electrode 313B formed on the upper insulating layer 12B. And, an opening portion 14 is formed through the second gate electrode 313B, the upper insulating layer 12B, the cathode electrode 111 and the lower insulating layer 12A. An edge portion 111A of the cathode electrode 111 is exposed on a side wall surface of the opening portion 14. A voltage is applied to the cathode electrode 111 and the first and second gate electrodes 13A and 313B, whereby electrons are emitted from the edge portion 111A of the cathode electrode 111 which edge portion corresponds to an electron-emitting portion.

[0330] The method of producing the edge-type field emission device shown, for example, in Fig. 42C will be explained with reference to Figs. 43A, 43B and 43C showing schematic partial end views of the supporting substrate and the like.

[Step-2100]

[0331] First, an approximately 0.2 μm thick tungsten layer is formed on the supporting substrate 10 made, for example, of a glass by a sputtering method, and the tungsten layer is patterned by photolithography and a dry etching method, to form the first gate electrode 13A in the from of a stripe. Then, the lower insulating layer 12A, which is composed of SiO_2 and has a thickness of approximately 0.3 μm, is formed on the entire surface, and then the cathode electrode 111 constituted of an electrically conductive material layer composed of tungsten in the form of a stripe is formed on the lower insulating layer 12A (see Fig. 43A).

[Step-2110]

[0332] Then, the upper insulating layer 12B, which, for example, is composed of SiO_2 and has a thickness of 0.7 μm. is formed on the entire surface, and then the second gate electrode 313B in the form of a stripe is formed on the upper insulating layer 12B (see Fig. 43B). The second gate electrode 313B is composed of a gas-trapping material.

[Step-2120]

[0333] Then, a resist layer 90 is formed on the entire surface, and a resist opening portion 90A is formed in the resist layer 90 such that part of the surface of the second gate electrode 313B is exposed. The resist opening portion 90A has a rectangular form when viewed as a plan view. The rectangular form has a major side length of 100 μm and a minor side length of several to 10 μm. Then, the second gate electrode 313B exposed in the bottom portion of the resist opening portion 90A is anisotropically etched, for example, by an RIE method, to form an opening portion. Then, the upper insulating layer 12B exposed in the bottom portion of the opening portion is isotropically etched to form an opening portion (see Fig. 43C). Since the upper insulating layer 12B is composed of SiO_2, wet etching is carried out using a buffered hydrofluoric acid aqueous solution. The side wall surface of the opening portion in the upper insulating layer 12B recedes from the opening end portion of the opening portion formed in the second gate electrode 313B. In this case, the recess amount can be controlled by adjusting the etching time period. In this embodiment, the wet etching is carried out until the lower end of the opening portion formed in the upper insulating layer 12B recedes from the opening end portion of the opening portion formed in the second gate electrode 313B.

[0334] The cathode electrode 111 exposed in the bottom portion of the opening portion is dry-etched under a condition where ions are used as main etching species. In the dry-etching using ions as main etching species, ions as charged particles can be accelerated by applying a biased voltage to an object to be etched or utilizing interaction of plasma and an electric field, and generally, anisotropic etching proceeds, so that the etched object has a perpendicular wall as a processed surface. In this step, however, the main etching species contain incidence components having angles different from the perpendicularity, and obliquely entering components are also generated due to scattering on the end portion of the opening portion, so that, at some probability, main etching species enter regions which ion originally should not reach since the regions are shielded by the opening portion. In this case, main etching species having a smaller incidence angle with regard to the normal of the supporting substrate 10 show a higher entering probability, and main etching species having a larger incidence angle show a lower entering probability.

[0335] Therefore, while the position of upper end portion of the opening portion formed in the cathode electrode 111 is nearly lined up with the lower end portion of the opening portion formed in the upper insulating layer 12B, the position of the lower end portion of the opening portion formed in the cathode electrode 111 is projected from the upper end portion thereof. That is, the thickness of the edge portion 111A of the cathode electrode 111 decreases toward the leading end portion in the projection direction, and the edge portion 111A is sharpened. For example, when SF6 is used as an etching gas, the cathode electrode 111 can be excellently processed.

[0336] The lower insulating layer 12A exposed in a bottom portion of the opening portion formed in the cathode electrode 111 is isotropically etched, to form an opening portion in the lower insulating layer 12A, whereby the opening portion 14 is completed. In this embodiment, wet etching is carried out using a buffered hydrofluoric acid aqueous solution. The side wall surface of the opening portion formed in the lower insulating layer 12A recedes from the lower end portion of the opening portion formed in the cathode electrode 111. In this case, the recess amount can be controlled by adjusting the etching time period. After the completion of the opening portion 14, the resist layer 90 is removed, whereby the constitution shown in Fig. 42C can be obtained.

Example 22

[0337] Example 22 is concerned with the method of producing a Spindt-type field emission device different from that in Example 2. The method of producing such a Spindt-type field emission device will be explained hereinafter with reference to Figs. 44A, 44B, 45A, 45B, 46A and 46B showing schematic partial end views of a supporting substrate, etc. The Spindt-type field emission device in this Example is produced basically according to the steps of;

(a') forming a cathode electrode 511 on a supporting substrate 510,
(b') forming an insulating layer 512 on the cathode electrode 511 and the supporting substrate 510,
(c') forming a gate electrode 313 on the insulating layer 512,
(d') forming an opening portion 514 having the cathode electrode 511 exposed in a bottom portion thereof, at least in the insulating layer 512,
(e') forming an electrically conductive material layer 521 for an electron-emitting portion on the entire surface including the inside of the opening portion 514,
(f') forming a mask material layer 522 on the electrically conductive material layer 521 so as to mask a region of the electrically conductive material layer 521 which region is positioned in a central portion of the opening portion 514, and
(g') etching the electrically conductive material layer 521 and the mask material layer 522 under an anisotropic etching condition where an etching rate of the electrically conductive material layer 521 in the direction perpendicular to the supporting substrate 510 is higher than an etching rate of the mask material layer 522 in the direction

perpendicular to the supporting substrate 510, to form an electron-emitting portion 15D which is constituted of the electrically conductive material layer 521 and has a top end portion having a conical form, on the cathode electrode 511 exposed in the opening portion 514.

[Step-2200]

[0338] The cathode electrode 511 composed of chromium (Cr) is formed on the supporting substrate 510 prepared, for example, by forming an approximately 0.6 µm thick SiO_2 layer on a glass substrate. Specifically, an electrically conductive material layer composed of chromium for a cathode electrode is deposited on the supporting substrate 510, for example, by a sputtering method or a CVD method, and the electrically conductive material layer is patterned, whereby there can be formed the electrically conductive material layer including a plurality of cathode electrodes 511 and being in the form of a stripe extending in parallel in a row direction. The electrically conductive material layer for a cathode electrode has a width, for example, of 50 (m and one electrically conductive material layer is spaced from another electrically conductive material layer at a distance, for example, of 30 µm. Then, the insulating layer 512 composed of SiO_2 is formed on the entire surface, specifically, on the cathode electrode 511 and the supporting substrate 510 by a plasma CVD method using TEOS (tetraethoxysilane) as a source gas. The insulating layer 512 has a thickness of approximately 1 µm. Then, the gate electrode 313 is formed on the entire surface on the insulating layer 512, the gate electrode 313 being formed of a gate-electrode-constituting layer in the form of a stripe and extending in the direction at right angles with the electrically conductive material layer for a cathode electrode.

[0339] Then, in an electron-emitting region where the electrically conductive material layer for a cathode electrode and the gate-electrode-constituting layer overlap, that is; in a one pixel region, opening portions 514 are formed through the gate-electrode-constituting layer and the insulating layer 512. The opening portion 514 has, for example, the form of a circle having a diameter of 0.3 µm when viewed as a plan view. Generally, hundreds to thousands of opening portions 514 are formed per one pixel region (one electron-emitting region). For forming the opening portions 514, while a resist layer formed by general photolithography is used as a mask, first, the opening portions 514 are formed in the gate-electrode-constituting layer, and the opening portions 514 are formed in the insulating layer 512. After RIE, the resist layer is removed by ashing (see Fig. 44A).

[Step-2210]

[0340] Then, an adhesion layer 520 is formed on the entire surface by a sputtering method (see Fig. 44B). The adhesion layer is provided for improving the adhesion of an electrically conductive material layer 521 to be formed in a step to follow to the insulating layer 512 exposed in a non-formed regions of the gate-electrode-constituting layer and to the side wall surfaces of the opening portions 514. On condition that tungsten is used to form the electrically conductive material layer 521, the adhesion layer 520, which is composed of tungsten, is formed as a 0.07 µm thick layer by a DC sputtering method.

[Step-2220]

[0341] The electrically conductive material layer 521 for an electron-emitting portion is formed on the entire surface including the inside of the opening portion 514 by a hydrogen reduction pressure reduced CVD method, the electrically conductive material layer 521 having a thickness of approximately 0.6 µm and being composed of tungsten (see Fig. 45A). In the surface of the formed electrically conductive material layer 521, formed is a recess 521A reflecting a step between the top end surface and the surface of bottom portion of the opening portion 514.

[Step-2230]

[0342] A mask material layer 522 is formed so as to cover a region (specifically, the recess 521A) of the electrically conductive material layer 521 which region is positioned in the central portion of the opening portion 514. Specifically, a 0.35 µm thick resist layer as the mask material layer 522 is formed on the electrically conductive material layer 521 by a spin coating method (see Fig. 45B). The mask material layer 522 absorbs the recess 521A of the electrically conductive material layer 521 to form a nearly flat surface. Then, the mask material layer 522 is etched by an RIE method using oxygen-containing gas. The etching is terminated when a flat surface of the electrically conductive material layer 521 is exposed, whereby the mask material layer 522 remains so as to form a flat surface by filling itself in the recess 521A of the electrically conductive material layer 521 (see Fig. 46A).

[Step-2240]

[0343] Then, the electrically conductive material layer 521, the mask material layer 522 and the adhesion layer 520 are etched to form a conical electron-emitting portion 15D (see fig. 46B). These are etched under an anisotropic etching condition where an etching rate of the electrically conductive material 521 is higher than an etching rate of the mask material layer 522. The following Table 4 shows the etching condition.

Table 4

Etching condition of electrically conductive material layer 521, etc.	
SF_6 flow rate	150 SCCM
O_2 flow rate	30 SCCM
Ar flow rate	90 SCCM
Pressure	35 Pa
RF power	0.7 kW (13.56 MHz)

[Step-2250]

[0344] Inside the opening portion 514 formed in the insulating layer 512, the side wall surface of the opening portion 514 is receded under an isotropic etching condition, whereby an field emission device shown in Fig. 47 is completed. The isotropic etching can be carried out a dry etching method using radical as main etching species such as chemical dry etching, or by a wet etching method using an etching solution. As an etching solution, for example, there may be used a mixture containing a 49 % hydrofluoric acid aqueous solution and pure water in a 49 % hydrofluoric acid aqueous solution/pure water volume ratio of 1/100.

[0345] The mechanism of forming the field emission device 15D in [Step2240] will be explained with reference to Figs. 48A and 48B. Fig. 48A schematically shows how the surface profile of a material to be etched changes at constant time intervals as the etching proceeds, and Fig. 48B is a graph showing a relationship between an etching time and a thickness of the material being etched in the center of the opening portion 514. The mask material layer has a thickness h_p in the center of the opening portion 514, and the electron-emitting portion 15D has a height h_e in the center of the opening portion 514.

[0346] Under the etching condition shown in Table 4, the etching rate of the electrically conductive material layer 521 is naturally higher than the etching rate of the mask material layer 522 composed of a resist material. In a region where no mask material layer 522 is present, the electrically conductive material layer 521 immediately begins to be etched, and the surface of the material being etched readily goes down. In contrast, in a region where the mask material layer 522 is present, the electrically conductive material layer 521 begins to be etched only after the mask material layer 522 is removed first. While the mask material layer 522 is etched, therefore, the decremental rate of thickness of the material being etched is low (h_p decremental interval), and the decremental rate of thickness of the material being etched comes to be as high as the etching rate in the region where no mask material layer 522 is present only when the mask material layer 522 disappears (h_e decremental interval). The time at which the h_e decremental interval begins comes the last in the center of the opening portion where the mask material layer 522 has a largest thickness, and comes earlier in a region nearer to the circumference of the opening portion 514 where the mask material layer 522 has a smaller thickness. In the above manner, the electron-emitting portion 15D having a conical form is formed.

[0347] The ratio of the etching rate of the electrically conductive material layer 521 to the etching rate of the mask material layer 522 composed of a resist material will be referred to as "selective ratio to a resist". The selective ratio to a resist is an important factor for determining the height and the form of the electron-emitting portion 15D. This point will be explained with reference to Figs. 49A, 49B and 49C. Fig. 49A shows a form of the electron-emitting portion 15D when the selective ratio to a resist is relatively small. Fig. 49C shows a form of the electron-emitting portion 15D when the selective ratio to a resist is relatively large. Fig. 49B shows a form of the electron-emitting portion 15D when the selective ratio to a resist is intermediate. It is seen that with an increase in the selective ratio to a resist, the film decrease of the electrically conductive material layer 521 is sharp as compared with the film decrease of the mask material layer 522, so that the electron-emitting portion 15D has a larger height and a sharper form. The selective ratio to a resist decreases with an increase in the O_2 flow rate relative to the SF_6 flow rate. When an etching apparatus which makes it possible to change the incidence energy of ion by co-using substrate bias is used, the selective ratio to a resist can be decreased by increasing the RF bias power or decreasing the frequency of AC current for bias application. When the selective ratio to a resist is selected, it is at least 1.5, preferably at least 2, more preferably at least 3.

[0348] In the above etching, naturally, it is required to secure a high selective etching ratio to the gate electrode 313

and the cathode electrode 511. Under the condition shown in Table 4, no problem is caused. The reason therefor is as below. The material constituting the gate electrode 313 or the cathode electrode 511 is hardly etched with fluorine-containing etching species so long as a proper material is selected. Under the above condition, a selective etching ratio of approximately 10 or more can be obtained.

Example 23

[0349] Example 23 is a variant of Example 22. In the production method in Example 23, the region of the electrically conductive material which region is covered with the mask material layer can be narrowed as compared with the production method in Example 22. In the method of producing a Spindt-type field emission device in Example 23, a nearly funnel-like recess having a columnar portion and a widened portion communicating with the upper end of the columnar portion is formed in a surface of the conductive material layer by utilizing a step between the upper end surface and the surface of bottom portion of the opening portion, and in the step (f'), the mask material layer is formed on the entire surface of the electrically conductive material layer. Then, the mask material layer and the electrically conductive material layer are removed in a plane in parallel with the surface of the supporting substrate, whereby the mask material layer is retained in the columnar portion.

[0350] The method of producing the Spindt-type field emission device in Example 23 will be explained hereinafter with reference to Figs. 50A, 50B, 51A, 51B, 52A and 52B showing schematic partial end views of a supporting substrate, etc.

[Step-2300]

[0351] First, the cathode electrode 511 is formed on the supporting substrate 510. That is, an electrically conductive material layer for a cathode electrode, including the cathode electrodes 511, is formed by stacking a TiN layer (thickness 0.1 μm), a Ti layer (thickness 5 nm), an Al-Cu layer (thickness 0.4 μm), a Ti layer (thickness 5 nm), a TiN layer (thickness 0.02 μm) and a Ti layer (thickness 0.02 μm) in this order, for example, by a DC sputtering method to form a stacked layer and patterning the stacked layer in the form of a stripe. Figures show the cathode electrode 511 as a single layer. Then, a 0.7 μm thick insulating layer 512 is formed on the entire surface, specifically, on the supporting substrate 510 and the cathode electrode 511 by a plasma CVD method using TEOS (tetraethoxysilane) as a source gas. Then, a gate-electrode-constituting layer in the form of a stripe, including the gate electrodes 313, is formed on the insulating layer 512.

[0352] Further, a 0.2 μm thick etching-stop layer 523 composed of SiO_2 is formed on the entire surface. The etching-stop layer 523 is not essential for the function of the field emission device but works to protect the gate electrode 313 when the electrically conductive material layer 521 is etched in a step to come later. When the gate electrode 313 has sufficiently high etching durability against an etching condition for the electrically conductive material layer 521, the etching-stop layer 523 may be omitted. Then, an opening portion 514 is formed through the etching stop layer 523, the gate electrode 313 and the insulating layer 512 by an RIE method. The cathode electrode 511 is exposed in a bottom portion of the opening portion 514. In this manner, a state shown in Fig. 50A is obtained. [Step-2310]

[0353] Then, a 0.03 μm thick adhesion layer 520 composed, for example, of tungsten is formed on the entire surface including the inside of the opening portion 514 (see Fig. 50B). Then, an electrically conductive material layer 521 for an electron-emitting portion is formed on the entire surface including the inside of the opening portion 514. In Example 23, the thickness of the electrically conductive material layer 521 is determined such that a recess 521A having a larger depth than the recess 521A in Example 22 is formed in the surface. That is, the thickness of the electrically conductive material layer 521 is properly determined, whereby there can be formed a nearly funnel-like recess 521A having a columnar portion 521B and a widened portion 521C communicating with the upper end of the columnar portion in the surface of the conductive material layer 521 by utilizing a step between the upper end surface and the surface of bottom portion of the opening portion 514.

[Step-2320]

[0354] Then, an approximately 0.5 μm thick mask material layer 522 composed of copper (Cu) is formed on the entire surface of the electrically conductive material layer 521 by an electroless plating method (see Fig. 51A). Table 5 shows a condition of the electroless plating.

Table 5

Plating solution	Copper sulfate ($CuSO_4$•$5H_2O$)	7 g/liter
	Formalin (37% HCHO)	20 ml/liter
	Sodium hydroxide (NaOH)	10 g/liter
	Potassium sodium tartarate	20 g/liter
Plating bath temperature	50°C	

[Step-2330]

[0355] Then, the mask material layer 522 and the electrically conductive material layer 521 are removed in a plane in parallel with the surface of the supporting substrate 510, to retain the mask material layer 522 in the columnar portion 521B (see Fig. 51B). The above removal can be carried out, for example by a chemical/mechanical polishing (CMP) method.

[Step-2340]

[0356] Then, the electrically conductive material layer 521, the mask material layer 522 and the adhesion layer 520 are etched under an anisotropic condition where etching rates of the electrically conductive material layer 521 and the adhesion layer 520 are higher than an etching rate of the mask material layer 522. As a result, an electron-emitting portion 15D having a conical form is formed in the opening portion 514 (see Fig. 52A). When the top end portion of the electron-emitting portion 15D has a residual mask material layer 522, the residual mask material layer 522 can be removed by a wet etching method using a diluted hydrofluoric acid aqueous solution.

[Step-2350]

[0357] Inside the opening portion 514 formed in the insulating layer 512, the side wall surface of the opening portion 514 is receded under an isotropic etching condition, whereby an field emission device shown in Fig. 52B is completed. For the isotropic etching, there can be employed those explained in the production method in Example 22.

[0358] Meanwhile, in the electron-emitting portion 15D formed in Example 23, a sharper conical form is formed than the counterpart in the electron emitting portion 15D formed in Example 22. This difference is caused by differences in form of the mask material layers 522 and the ratio of the etching rate of electrically conductive material layer 521 to the etching rate of the mask material layer 522. The above differences will be explained with reference to Figs. 53A and 53B. Figs. 53A and 53B show how the surface profile of a material being etched changes at constant intervals of time. Fig. 53A shows a case using a mask material layer 522 composed of copper, and Fig. 53B shows a case using a mask material layer 522 composed of a resist material. For simplification, it is assumed that the etching rate of the electrically conductive material layer 521 and the etching rate of the adhesion layer 520 are the same, and showing of the adhesion layer 520 is omitted.

[0359] When the mask material layer 522 composed of copper is used (see Fig. 53A), the mask material layer 522 disappears in no case during etching since the etching rate of the mask material layer 522 is sufficiently low as compared with the etching rate of the electrically conductive material layer 521, so that an electron-emitting portion having a sharp top end portion can be formed. In contrast, when a mask material layer 522 composed of a resist material is used (see Fig. 53B). the mask material layer 522 is liable to disappear during the etching since the etching rate of the mask material layer 522 is not so high as the etching rate of the electrically conductive material layer 521. After the mask material layer disappears, therefore, the conical form of the electron-emitting portion 15D tends to become obtuse.

[0360] Further, the mask material layer 522 remaining in the columnar portion 521B has a merit that the form of the electron-emitting portion 15D does not much change even if the depth of the columnar portion 521B changes to some extent. That is, the depth of the columnar portion 521B can vary depending upon the thickness of the electrically conductive material layer 521 and the fluctuation of the step coverage. Since, however, the width of the columnar portion 521B is nearly constant regardless of the depth. the width of the mask material layer 522 comes to be nearly constant, so that there is not much difference in the form of the electron-emitting portion 15D finally formed. In contrast, in the mask material layer 522 retained in the recess 521A, the width of the mask material layer changes depending upon whether the recess has a large depth or a small depth, so that the conical form of the electron-emitting portion 15D begins to become obtuse earlier when the recess 521A is shallower and when the mask material layer 522 has s smaller thickness. The electron emission efficiency of the field emission device changes depending upon a potential

difference between the gate electrode and the cathode electrode, a distance between the gate electrode and the cathode electrode and a work function of a material constituting the electron-emitting portion, and it also changes depending upon the form of top end portion of the electron emitting portion. It is therefore preferred to make the above selection of the form and the etching rate of the mask material layer as required.

Example 24

[0361] Example 24 is a variant of the method of producing the Spindt-type field emission device of Example 23. In the production method of Example 24, a nearly funnel-like recess having a columnar portion and a widened portion communicating with the upper end portion of the columnar portion is formed in a surface of the electrically conductive material layer in step (e'), the columnar portion reflecting a step between the upper end surface and the surface of bottom portion of the opening portion, and in step (f'), the mask material layer is formed on the entire surface of the electrically conductive material layer, and the mask material layer on the electrically conductive material layer and inside the widened portion is removed, whereby the mask material layer is retained in the columnar portion. The method of producing the Spindt-type field emission device in Example 24 will be explained hereinafter with reference to Figs. 54A, 54B and 55 showing schematic partial end views of the supporting substrate, etc.

[Step-2400]

[0362] Procedures up to the formation of the mask material layer 522 shown in Fig. 51A are carried out in the same manner as in [Step-2300] to [Step2320] in Example 23. and then the mask material layer 522 only on the electrically conductive material layer 521 and inside the widened portion 521C is removed, to retain the mask material layer 522 in the columnar portion 521B (see Fig. 54A). In this case, wet etching is carried out, for example, with a diluted hydrofluoric acid aqueous solution, whereby only the mask material layer 522 composed of copper can be selectively removed without removing the electrically conductive material layer 521 composed of tungsten. The height of the mask material layer 522 remaining in the columnar portion 521B differs depending upon the etching time period. However, the etching time period is not so strict so long as the mask material layer 522 filled in the widened portion 521C is fully removed. The reason therefor is as follows. A discussion on the height of the mask material layer 522 is substantially the same as the above discussion made on the depth of the columnar portion 521B with reference to Fig. 53A, and the height of the mask material layer 522 has no major effect on the form of the electron-emitting portion 15D to be finally formed.

[Step-2410]

[0363] Then, the electrically conductive material layer 521, the mask material layer 522 and the adhesion layer 520 are etched in the same manner as in Example 23, to form the electron-emitting portion 15D shown in Fig. 54B. While the electron-emitting portion 15D may naturally have a conical form as a whole as shown in Fig. 52A, Fig. 54B shows a variant in which a top portion alone has a conical form. Such a form is produced when the height of the mask material layer 522 filled in the columnar portion 521B is small or when the etching rate of the mask material layer 522 is relatively high. Such a form does not at all affect the function of the electron-emitting portion 15D.

[Step-2420]

[0364] In the opening portion 514 formed in the insulating layer 512, the side wall surface of the opening portion 514 is receded under an isotropic etching condition, whereby the field emission device shown in Fig. 55 is completed. The isotropic etching can be carried out in the same manner as in the production method explained in Example 22.

Example 25

[0365] The production method of Example 25 is a variant of the production method of Example 22. Fig. 56 shows a schematic partial end view in Example 25. Example 25 differs from Example 22 in that the electron-emitting portion has a base 530 and a conical electron-emitting portion 15D formed on the base 530. The base 530 is composed of one material, and the electron-emitting portion 15D is composed of another material. Specifically, the base 530 is a member for adjusting a distance between the electron-emitting portion 15D and the opening end portion of the gate electrode 313, has a function as a resistance layer and is constituted of a polysilicon layer containing an impurity. The electron-emitting portion 15D is composed of tungsten, and has a conical form, more specifically, the form of a circular cone. An adhesion layer 520 composed of TiN is formed between the base 530 and the electron-emitting portion 15D. The adhesion layer 520 is not a component essential for the function of the electron-emitting portion but is provided

for a production-related reason. The insulating layer 512 is scraped from immediately below the gate electrode 313 toward the upper end portion of the base 530. to form an opening portion 514.

[0366] The production method of Example 25 will be explained hereinafter with reference to Figs. 57A, 57B, 58A, 58B, 59A and 59B.

[Step-2500]

[0367] First, procedures up to the formation of the opening portion 514 are carried out in the same manner as in [Step-2200] in the production method of Example 22. Then, an electrically conductive material layer 530A for forming the base is formed on the entire surface including the inside of the opening portion 514. The electrically conductive material layer 530A also works as a resistance layer, is constituted of a polysilicon layer and can be formed by a plasma CVD method. Then, a flattening layer 531 constituted of a resist layer is formed on the entire surface so as to form a nearly flat surface (see Fig. 57A). Then, the flattening layer 531 and the electrically conductive material layer 530A are etched under a condition where etching rates of these layers are nearly the same, to fill part of the opening portion 514 with the base portion 530 having a flat upper surface (see Fig. 57B). The etching can be carried out by an RIE method using an etching gas containing a chlorine-containing gas and an oxygen-containing gas. Since the surface of the electrically conductive material layer 530A is flattened with the flattening layer 531, the base 530 comes to have a flat upper surface.

[Step-2510]

[0368] Then, an adhesion layer 520 is formed on the entire surface including the inside of rest of the opening portion 514, and an electrically conductive material layer 521 for an electron-emitting portion is formed on the entire surface including the inside of rest of the opening portion 514, to fill the rest of the opening portion 514 with the electrically conductive material layer 521 (see Fig. 58A). The adhesion layer 520 is a 0.07 μm thick TiN layer formed by a sputtering method, and the electrically conductive material layer 521 is a 0.6 μm thick tungsten layer formed by a reduced pressure CVD method. A recess 521A reflecting a step between the upper end surface and the surface of bottom portion of the opening portion 514 is formed in the surface of the electrically conductive material layer 521.

[Step-2520]

[0369] Then, a mask material layer 522 constituted of a resist layer is formed on the entire surface of the electrically conductive material layer 521 by a spin coating method to form a nearly flat surface (Fig. 58B). The mask material layer 522 absorbs the recess 521A in the surface of the electrically conductive material layer 521 and forms a nearly flat surface. Then, the mask material layer 522 is etched by an RIE method using an oxygen gas (see Fig. 59A). The etching is terminated when a flat surface of the electrically conductive material layer 521 is exposed. In this manner, the mask material layer 522 is retained in the recess 521 A of the electrically conductive material 521 to form a flat surface, and the mask material layer 522 is formed so as to cover a region of the electrically conductive material layer 521 which region is positioned in the center of the opening portion 514.

[Step-2530]

[0370] Then, the electrically conductive material layer 521, the mask material layer 522 and the adhesion layer 520 are etched together in the same manner as in [Step-2240] in the production method of Example 22, whereby the electron-emitting portion 15D having a conical form depending upon the selective ratio to a resist based on the above-described mechanism and the adhesion layer 520 are formed, and the electron-emitting portion is completed (see Fig. 59B). Then, inside the opening portion 514 formed in the insulating layer 512, the side wall surface of the opening portion 514 is receded, whereby an field emission device shown in Fig. 56 can be obtained.

Example 26

[0371] The production method of Example 26 is a variant of the production method of Example 23. Fig. 61B shows a schematic partial end view in Example 26. Example 26 differs from Example 23 in that the electron-emitting portion has a base 530 and a conical electron-emitting portion 15D formed on the base 530 like the electron-emitting portion in Example 25. The base 530 is composed of one material, and the electron-emitting portion 15D is composed of another material. Specifically, the base 530 is a member for adjusting a distance between the electron-emitting portion 15D and the opening end portion of the gate electrode 313, has a function as a resistance layer and is constituted of a polysilicon layer containing an impurity. The electron-emitting portion 15D is composed of tungsten, and has a conical

form, more specifically, the form of a circular cone. An adhesion layer 520 composed of TiN is formed between the base 530 and the electron-emitting portion 15D. The adhesion layer 520 is not a component essential for the function of the electron-emitting portion but is provided for a production-related reason. The insulating layer 512 is scraped from immediately below the gate electrode 313 toward the upper end portion of the base 530, to form an opening portion 514.

[0372] The production method of Example 26 will be explained hereinafter with reference to Figs. 60A, 60B, 61A and 61B showing schematic partial end views of a supporting substrate, etc.

[Step-2600]

[0373] First, procedures up to the formation of the opening portion 514 are carried out in the same manner as in [Step-2200] in the production method of Example 22. Then. an electrically conductive material layer for forming the base is formed on the entire surface including the inside of the opening portion 514, and the electrically conductive material layer is etched, whereby the base 530 filling part of the opening portion 514 can be fomed. While the base 530 shown in Figures has a flat surface, the surface may be dented. The base 530 having a flat surface can be formed in the same manner as in [Step-2500] in the production method of Example 25. Further, the adhesion layer 520 and the electrically conductive material layer 521 for an electron-emitting portion are consecutively formed on the entire surface including the inside of rest of the opening portion 514. In this case, the thickness of the electrically conductive material layer 521 is determined such that a nearly funnel-like recess 521A having a columnar portion 521B and a widened portion 521C communicating with the upper end portion of the columnar portion 521B is formed in a surface of the electrically conductive material layer 521, the columnar portion 521B reflecting a step between the upper end surface of the rest of the opening portion 514 and the surface of the bottom portion thereof. Then, the mask material layer 522 is formed on the electrically conductive material layer 521. The mask material layer 522 is composed, for example, of copper. Fig. 60A shows the thus-completed state.

[Step-2610]

[0374] The mask material layer 522 and the electrically conductive material layer 521 are removed in a plane in parallel with the surface of the supporting substrate 510, to retain the mask material layer 522 in the columnar portion 521B (see Fig. 60B). The above removal can be carried out by a chemical mechanical/polishing method (CMP method) in the same manner as in [Step-2330] in Example 23.

[Step-2620]

[0375] Then, the electrically conductive material layer 521, the mask material layer 522 and the adhesion layer 520 are etched, to form an electron-emitting portion 15D having a conical form depending upon the selective ratio to a resist based on the above-described mechanism. These layers can be etched in the same manner as in [Step-2340] in the production method of Example 23. The electron-emitting portion comprises the electron-emitting portion 15D, the base 530 and the adhesion layer 520 remaining between the electron-emitting portion 15D and the base 530. While the electron-emitting portion may naturally have a conical form as a whole, Fig. 61A shows a state where the base 530 is filled in part of the opening portion 514. Such a form is produced when the mask material layer 522 filled in the columnar portion 521 has a small height or when the etching rate of the mask material layer 522 is relatively high. The above form does not at all affect the function of the electron-emitting portion.

[Step-2630]

[0376] Then, inside the opening portion 514, the side wall surface of the insulating layer 512 is receded under an isotropic etching condition, whereby an field emission device shown in Fig. 61B is completed. The isotropic etching condition can be the same as those explained in the production method of Example 22.

Example 27

[0377] The production method of Example 27 is a variant of the method of producing the Spindt-type field emission device in Example 24. Example 27 differs from Example 24 in that the electron-emitting portion has a base 530 and a conical electron-emitting portion 15D formed on the base 530 like Example 25. The method of producing the Spindt-type field emission device in Example 27 will be explained hereinafter with reference to Fig. 62 showing a schematic partial end view of a supporting substrate, etc.

[Step-2700]

[0378] Procedures up to the formation of the mask material layer 522 are carried out in the same manner as in [Step-2600] in the production method of Example 26. Then, only the mask material layer 522 on the electrically conductive material layer 521 and in the widened portion 521C is removed, thereby to retain the mask material layer 522 in the columnar portion 521B (see Fig. 62). The mask material layer 522 composed of copper can be selectively removed without removing the electrically conductive material layer 521 composed of tungsten, for example, by wet etching with a diluted hydrofluoric acid aqueous solution. Thereafter, all the steps of etching the electrically conductive material layer 521 and the mask material layer 522, isotropically etching the insulating layer 512, etc., can be carried out in the same manner as in the production method of Example 26.

[0379] The present invention has been explained with reference to Examples hereinabove, while the present invention shall not be limited thereto. Particulars of constitutions of the field emission devices and the flat-panel displays explained in Examples are given as examples and may be altered as required.

[0380] Various materials used in the production of the field emission devices are also give as examples and may be altered as required. While the field emission devices are explained as embodiments in which one electron-emitting portion corresponds to one opening portion, there may be employed an embodiment in which a plurality of electron-emitting portions correspond to one opening portion or one electron-emitting portion corresponds to a plurality of opening portions, depending upon the structures of the field emission devices. Further, there may be employed an embodiment in which a plurality of opening portions are formed in the gate-electrode-constituting layer, one opening portion communicating with a plurality of such opening portions is formed in the insulating layer, and one or a plurality of electron-emitting portions is or are formed.

[0381] The method of driving the flat-panel display shall not be limited to the method explained in Examples. Further, the form of the gate electrode or the electrically conductive material layer for a gate electrode shall not be limited to the form of a stripe. There may be employed a constitution in which all the gate electrodes constituting the first panel P_1 of the flat-panel display are constituted of one sheet-like electrode-constituting layer (for example, a single-layered structure composed of a gas-trapping material or a stacked structure formed of a first layer composed of an electrically conductive material or an electrically insulating material and a second layer (gas-trapping layer) composed of a gas-trapping material). In such constitutions, the cathode electrode has, for example, a rectangular plan form corresponding to one pixel. In some cases, it is not required to provide a spacer per cold cathode field emission device.

[0382] Fig. 63 shows a circuit for driving the above-constituted flat-panel display. The circuit has a control circuit 30 electrically connected to the electron-emitting portions (more specifically, the cathode electrodes 11) and a gate-electrode control circuit (not shown) electrically connected to the gate electrodes 313. Further, the control circuit 30 has a data circuit 130A and a scanning circuit 130B. Each cathode electrode 11 is electrically connected to the data circuit 130A through a switching element 130C constituted of a MOS transistor. The gate portion of the MOS transistor is electrically connected to the scanning circuit 130B. The MOS transistor is, for example, an n-channel type MOS transistor and works as a switching element which controls ON and OFF depending upon control signals applied from the scanning circuit 130B and the data circuit 130A. When the switching element 130C comes to be in an ON state, a voltage depending upon the control signals applied from the scanning circuit 130B and the data circuit 130A is applied to the cathode electrode 11 electrically connected to the switching element 130C. The MOS transistor may be constituted of a p-channel type MOS transistor. Further, the MOS transistor may be replaced with other switching means having the switching function equivalent to that of the MOS transistor.

[0383] The field emission devices arranged in the row direction (X direction) are consecutively driven in the column direction (Y direction). Specifically, a constant voltage V_G is applied to one sheet-like gate-electrode-constituting layer having the gate electrodes 313 from the gate-electrode control circuit. A desired switching element 130C is brought into an ON state with the control circuit 30, thereby to apply a voltage of $0 \leq [V_{C\text{-}MAX}$ to $V_{C\text{-}MIN}]$ ($<V_G$) to each cathode electrode 11. In an electron-emitting region having the gate electrode 313 to which the voltage VG is applied and each cathode electrode 11 to which the voltage of $0 \leq [V_{C\text{-}MAX}$ to $V_{C\text{-}MIN}]$ is applied, a potential difference ΔV is the maximum when (V_G - $V_{C\text{-}MIN}$), and the quantity of electrons emitted from the electron-emitting region is the largest, and the electrons are attracted to the anode electrode 23 to collide with the fluorescent layer 21. As a result, the fluorescent layer corresponding to such an electron-emitting region has the largest light emission brightness. On the other hand, when (V_G - V_C-MAX), the potential difference ΔV is the smallest, no electrons are emitted from the electron-emitting region, and the fluorescent layer corresponding to such an electron-emitting region does not emit light. The light emission brightness of the fluorescent layer can be controlled by applying a voltage of $V_{C\text{-}MAX}$ to $V_{C\text{-}MIN}$ to the electrically conductive material layers for a cathode electrode.

[0384] Otherwise, there may be employed a constitution in which all of the cathode electrodes constituting the first panel P_1 of the flat-panel display are constituted of one sheet-like electrically conductive material layer and the gate electrode 313 is constituted of an electrically conductive material layer in the form of a stripe. That is, the gate electrode 313 has, for example, a rectangular plan form corresponding to one pixel. As shown in Fig. 64, a circuit for driving the

flat-panel display can comprise a cathode-electrode control circuit (not shown) electrically connected to the electron-emitting portions (specifically, the cathode electrodes) and a control circuit 31 electrically connected to the gate electrodes 313. The control circuit 31 has a data circuit 131A and a scanning circuit 131B. The gate electrode 313 is electrically connected to the data circuit 13 lA through a switching element 131C constituted of a MOS transistor. The gate portion of the MOS transistor is electrically connected to the scanning circuit 131B. The MOS transistor is, for example, an n-channel type MOS transistor, and works as a switching element which controls ON and OFF depending upon control signals applied from the scanning circuit 131B and the data circuit 131A. When the switching element 131C is brought into an ON state, a voltage depending upon the control signals applied from the scanning circuit 131B and the data circuit 131A is applied to the gate electrode 313 electrically connected to the switching element 131C. The MOS transistor may be constituted of a p-channel type MOS transistor. Further, the MOS transistor may be replaced with other switching means having the switching function equivalent to that of the MOS transistor.

[0385] In the above flat-panel display, the field emission devices arranged in the row direction (X direction) are consecutively driven in the column direction (Y direction). Specifically, a constant voltage V_C is applied to one sheet-like cathode-electrode-constituting layer having the cathode electrodes 11 from the cathode-electrode control circuit. A desired switching element 131C is brought into an ON state with the control circuit 31, thereby to apply a voltage of $V_C \leq [V_{G\text{-}MAX}$ to $V_{G\text{-}MIN}]$ to each gate electrode 313. In an electron-emitting region having the cathode electrode 11 to which the voltage V_C is applied and each gate electrode 313 to which the voltage of $V_{G.MAX}$ to $V_{G\text{-}MIN}$ is applied, a potential difference ΔV is the maximum when ($V_{G\text{-}MAX}$ - V_C), and the quantity of electrons emitted from the electron-emitting region is the largest, and the electrons are attracted to the anode electrode 23 to collide with the fluorescent layer 21. As a result, the fluorescent layer corresponding to such an electron-emitting region has the largest light emission brightness. On the other hand, when ($V_{G\text{-}MIN}$ - V_C), the potential difference ΔV is the smallest, no electrons are emitted from the electron-emitting region, and the fluorescent layer corresponding to such an electron-emitting region does not emit light. The light emission brightness of the fluorescent layer can be controlled by applying a voltage of $V_{G\text{-}MAX}$ to $V_{G\text{-}MIN}$ to the gate electrodes 13.

[0386] Further, the electron-emitting region can be also constituted of devices generally called surface conduction type field emission devices. The surface conduction type field emission device comprises a substrate made of a glass and pairs of electrodes formed on the substrate in the form of matrix, the electrodes being composed of an electrically conductive material such as tin oxide (SnO_2), gold (Au), indium oxide (In_2O_3)/tin oxide (SnO_2), carbon or palladium oxide (PdO), having a fine area and a pair of electrodes being arranged at constant intervals (gaps). A carbon thin film is formed on each electrode. A row-direction wiring is connected to one electrode of a pair of the electrodes, and a columndirection wiring is connected to the other electrode. When a voltage is applied to a pair of the electrodes, an electric field is applied to the carbon thin films opposed to each other through the gap, and electrons are emitted from the carbon thin film. Such electrons are allowed to collide with a fluorescent layer on a second panel (anode panel) to excite the fluorescent layer, whereby a desired image can be obtained.

[0387] In Examples, while the focus electrode 47 or 147 is provided above the gate electrode through the second insulating layer 46. a focus electrode 247 may be provided above the gate electrode through a vacuum layer. In this case, the focus electrode 247 can substantially have the same structure as that of the focus electrode 147 in Example 10. Further, a gate electrode 313 can be structured as explained in Examples of the present invention, or it may have a conventional structure in some cases. The focus electrode 247 can be composed, for example, of one sheet-like material. The above focus electrode 247 is fixed to the second panel P_2 through a supporting member 248 arranged in a circumferential portion of the second panel P_2. The focus electrode 247 may have a single-layered structure composed of a gas-trapping material (composed, for example, of a titanium alloy having a thickness of 50 μm) or may have a stacked structure constituted, at least, of a first layer composed of an electrically conductive material or an electrically insulating material and a second layer composed of a gas-trapping material. Specifically, the latter can have a constitution similar to the constitution of the gate electrode explained with reference to Figs. 19A, 19B, 20A, 20B and 20C. When the focus electrode 247 has a stacked structure, it is preferred to arrange the second layer composed of a gas-trapping material on the cathode electrode side from the viewpoint that the vacuum state around the cathode electrode 11 is maintained under a better condition. That is. it is preferred to reverse the stacking order of the first layer 113A and the second layer 113B in Figs. 19A, 20A, 20B and 20C. In the focus electrode 247, an opening portion may be formed per field emission device, or one opening portion may be formed per a plurality of (for example, per pixel) of field emission devices.

[0388] As is clear from the above explanations, the getter of the present invention has a large effective area for exhibiting a gas-trapping effect and can achieve excellent gas-trapping efficiency over any conventional getter. In the flat-panel display of the present invention, the getter is provided in at least one of the first panel and the second panel, so that the gas-trapping efficiency is improved as compared with any conventional flat-panel display having a getter in one place of the ineffective field. As a result, the flat-panel display is remarkably improved in lifetime and image quality. Gas, etc., released into the vacuum layer are trapped in the gate electrode, the focus electrode or the getter, and a high vacuum atmosphere can be maintained in the vacuum layer. Even if gas molecules, ions, etc., are released,

for example, from the fluorescent layer, therefore, these are trapped in the gate electrode, the focus electrode or the getter, so that the collision thereof with the electron-emitting portions can be prevented. As a result, the occurrence of local discharging can be prevented, or a change in work function on the surface of the electron-emitting portion or the deterioration of the electron-emitting portions can be prevented, so that the electron-emitting portions can be imparted with a longer lifetime and that the performance can be stabilized by preventing the deterioration of image display. Further, since a conventional getter box is no longer necessary, the structure of a flat-panel display can be simplified. In the production method according to the third or fourth constitution of the present invention, the gate electrode or the focus electrode of the cold cathode field emission device is formed to have a pattern different from the pattern of the getter, the effective area of the getter can be further increased.

Claims

1. A getter (43A; 43B; 43C) comprising a support member (41) which is formed on a substratum (40) and which has a convexo-concave surface or is constituted of a porous material member (45), and a gas-trapping layer (42) formed on the support member in conformity with the surface of the support member.

2. The getter (43A; 43B) according to claim 1, wherein the supporting member (41) having a convexo-concave surface is constituted of nearly hemispherical silicon particles.

3. The getter (43C) according to claim 1, wherein the supporting member constituted of a porous material member (45) consists of at least one material selected from the group consisting of silicon oxide, silicon nitride and silicon oxide nitride.

4. A flat-panel display comprising a first panel (P_1) and a second panel (P_2) which are opposed to each other through a vacuum layer (VAC) and have effective fields (EF_1, EF_2) where pixels are arranged, wherein the effective field of at least one of the first panel and the second panel is provided with a getter for maintaining a vacuum degree of the vacuum layer.

5. The flat-panel display according to claim 4, wherein the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and each of the cold cathode field emission devices comprises;

    (A) an insulating layer (12) formed on a supporting substrate (10),
    (B) a gate electrode (13) formed on the insulating layer (12).
    (C) an opening portion (14) which penetrates through the gate electrode (13) and is formed in the insulating layer (12), and
    (D) an electron-emitting portion (15) formed in the opening portion (14), and

    the getter (43A; 43B; 43C) is provided on the gate electrode (13) and/or on the insulating layer (12) between one gate electrode and another gate electrode which are adjacent to each other.

6. The flat-panel display according to claim 5, wherein the getter comprises a support member (41) which has a convexo-concave surface or is constituted of a porous material member (45), and a gas-trapping layer (42) formed on the support member in conformity with the surface of the support member, and the support member (41) is formed on the gate electrode (15) and/or on the insulating layer (12) between one gate electrode and another gate electrode which are adjacent to each other.

7. The flat-panel display according to claim 4, wherein the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and each of the cold cathode field emission devices comprises;

    (A) an insulating layer (12) formed on a supporting substrate (10),
    (B) a gate electrode (13) formed on the insulating layer (12),
    (C) a second insulating layer (46) formed on the gate electrode (13) and the insulating layer (12),
    (D) a focus electrode (47) formed on the second insulating layer (46),
    (E) an opening portion (14) which penetrates through the focus electrode (47), the second insulating layer (46) and the gate electrode (13) is formed in the insulating layer (12), and

(F) an electron-emitting portion (15) formed in the opening portion (14), and

the getter (43B) is provided on the focus electrode (47) and/or on the second insulating layer (46) between one focus electrode and another focus electrode which are adjacent to each other.

8. The flat-panel display according to claim 7, wherein the getter comprises a support member (41) which has a convexo-concave surface or is constituted of a porous material member (45), and the support member is formed on the focus electrode (47) and/or on the second insulating layer (46) between one focus electrode and another focus electrode which are adjacent to each other.

9. The flat-panel display according to claim 6 or 8, wherein the supporting member having a convexo-concave surface is constituted of nearly hemispherical silicon particles.

10. The flat-panel display according to claim 6 or 8, wherein the supporting member constituted of a porous material member (45) consists of at least one material selected from the group consisting of silicon oxide, silicon nitride and silicon oxide nitride.

11. The flat-panel display according to claim 4, wherein the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and each of the cold cathode field emission devices comprises;

(A) an insulating layer (12) formed on a supporting substrate (10),
(B) a gate electrode (113) which is formed on the insulating layer (12) and at least part (113B) of which is composed of a gas-trapping material,
(C) an opening portion (14) which penetrates through the gate electrode (113) and is formed in the insulating layer (12), and
(D) an electron-emitting portion (15) formed in the opening portion (14), and

the gate electrode (113) works as the getter.

12. The flat-panel display according to claim 4, wherein the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and each of the cold cathode field emission devices comprises;

(A) an insulating layer (12) formed on a supporting substrate (10),
(B) a gate electrode (13) formed on the insulating layer (12),
(C) a second insulating layer (46) formed on the gate electrode (13) and on the insulating layer (12).
(D) a focus electrode (147) which is formed on the second insulating layer (46) and at least part of which is composed of a gas-trapping material,
(E) an opening portion (14) which penetrates through the focus electrode (147), the second insulating layer (46) and the gate electrode and is formed in the insulating layer (12), and
(F) an electron-emitting portion (15) formed in the opening portion (14), and

the focus electrode works (147) as the getter.

13. The flat-panel display according to claim 11 or 12, wherein the focus electrode (147) has a single-layered structure composed of a gas-trapping material.

14. The flat-panel display according to claim 11 or 12, wherein the focus electrode (147) has a stacked structure constituted, at least, of a first layer composed of an electrically conductive material or an electrically insulating material and a second layer composed of a gas-trapping material.

15. The flat-panel display according to any one of claims 5, 11 and 12, wherein a cathode electrode (11) is formed on the supporting substrate (10); the insulating layer (12) is formed on the cathode electrode and the supporting substrate; and the electron-emitting portion (15) is formed on the cathode electrode positioned in the bottom portion of the opening portion (14).

16. The flat-panel display according to any one of claims 5, 11 and 12, wherein an electron-emitting layer is formed

on the supporting substrate; the insulating layer is formed on the electron-emitting layer and the supporting substrate; and the electron-emitting layer positioned in the bottom portion of the opening portion corresponds to the electron-emitting portion (15).

17. The flat-panel display according to any one of claims 5, 11 and 12, wherein the insulating layer (12) covers an electron-emitting layer; the opening portion (14) penetrates through the electron-emitting layer; and an edge portion of the electron-emitting layer exposed on a side wall surface of the opening portion corresponds to the electron-emitting portion (15).

18. The flat-panel display according to claim 4, wherein the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and each of the cold cathode field emission devices comprises;

(A) a spacer (12) disposed on a supporting substrate (10) and composed of an electrically insulating material,
(B) a gate electrode (213) constituted of a gas-trapping material layer (213A) which has a plurality of opening portions (214A) formed therein and at least part of which is composed of a gas-trapping material, and
(C) an electron-emitting portion (15C) formed on the supporting substrate (10), and

the gas-trapping material layer (213A) is fixed such that it comes in contact with the top surface of the spacer (12) and that the opening portion is positioned above the electron-emitting portion (15C).

19. A method of producing a flat-panel display comprising a first panel (P_1) and a second panel (P_2) which are opposed to each other through a vacuum layer (VAC), have effective fields (EF_1, EF_2) where pixels are arranged, and are bonded to each other in circumferential portions thereof, the method including the step of forming a getter in the effective field of at least one of the first panel and the second panel.

20. The method of producing a flat-panel display according to claim 19, wherein the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and the first panel is produced by the steps of;

(a) forming an insulating layer (12) on a supporting substrate (10),
(b) forming an electrically conductive material layer (13') for a gate electrode (13) on the insulating layer (12).
(c) forming a getter-forming layer (43) on the electrically conductive material layer (13'),
(d) patterning the getter-forming layer (43) and the electrically conductive material layer (13') to form a gate electrode having a getter (43B) formed on the top surface of the gate electrode,
(e) forming an opening portion (14) at least in the insulating layer (12), and
(f) forming or exposing an electron-emitting portion (15) in the opening portion.

21. The method of producing a flat-panel display according to claim 19, wherein the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and the first panel is produced by the steps of;

(a) forming an insulating layer (12) on a supporting substrate (10),
(b) forming a gate electrode (13) on the insulating layer,
(c) forming a second insulating layer (46) on the insulating layer (12) and the gate electrode (13),
(d) forming an electrically conductive material layer (47') for a focus electrode (47) on the second insulating layer (46),
(e) forming a getter-forming layer (43) on the electrically conductive material layer (47'),
(f) patterning the getter-forming layer (43) and the electrically conductive material layer (47') to form a focus electrode (47) having a getter formed on the top surface of the focus electrode,
(g) forming an opening portion (14) at least in the second insulating layer (46) and in the insulating layer (12), and
(h) forming or exposing an electron-emitting portion (15) in the opening portion.

22. The method of producing a flat-panel display according to claim 20 or 21, wherein the step of forming a getter-forming layer comprises (1) the step of forming a supporting member (41) which has a convexo-concave surface or is constituted of a porous material member (45), on the electrically conductive material layer (47') for a focus electrode (47), and (2) the step of forming a gas-trapping layer which is in conformity with the surface of the

supporting member, on the supporting member.

23. The method of producing a flat-panel display according to claim 19, wherein the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and the first panel is produced by the steps of;

(a) forming an insulating layer (12) on a supporting substrate,
(b) forming a gate electrode (13) on the insulating layer (12),
(c) forming a getter (43B) on the gate electrode (13) and/or on the insulating layer (12) between one gate electrode and another gate electrode which are adjacent to each other,
(d) forming an opening portion (14) at least in the insulating layer (12), and
(e) forming or exposing an electron-emitting portion (15) in the opening portion (14).

24. The method of producing a flat-panel display according to claim 19, wherein the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and the first panel is produced by the steps of;

(a) forming an insulating layer (12) on a supporting substrate (10),
(b) forming a gate electrode (13) on the insulating layer (12),
(c) forming a second insulating layer (46) on the insulating layer (12) and the gate electrode (13),
(d) forming a focus electrode (47) on the second insulating layer (46),
(e) forming a getter (43B) on the focus electrode (47) and/or on the second insulating layer (46) between one focus electrode and another focus electrode which are adjacent to each other,
(f) forming an opening portion (14) at least in the second insulating layer (46) and in the insulating layer (12), and
(g) forming or exposing an electron-emitting portion (15) in the opening portion (14).

25. The method of producing a flat-panel display according to claim 23 or 24, wherein the step of forming a getter comprises (1) the step of forming a supporting member (41) which has a convexo-concave surface or is constituted of a porous material member (45), on the focus electrode (47) and/or on the second insulating layer (46) between one focus electrode and another focus electrode which are adjacent to each other, and (2) the step of forming a gas-trapping layer which is in conformity with the surface of the supporting member, on the supporting member.

26. The method of producing a flat-panel display according to claim 22 or 25, wherein, in the step (1), nearly hemispherical silicon particles are formed as the supporting member (41) having a convexo-concave surface.

27. The method of producing a flat-panel display according to claim 22 or 25, wherein, in the step (1), the supporting member constituted of a porous material member (45) is formed from at least one material selected from the group consisting of silicon oxide, silicon nitride and silicon oxide nitride.

28. The method of producing a flat-panel display according to claim 27, wherein the supporting member constituted of a porous material member (45) is formed by a process including the step of forming a supporting-member-forming film having a pyrolyzable group or containing a solvent and the step of heat-treating the supporting-member-forming film to pyrolyze the pyrolyzable group or to volatilize the solvent.

29. The method of producing a flat-panel display according to claim 27, the supporting member constituted of a porous material member (45) is formed by a process including the step of forming a supporting-member-forming film containing a plurality of components having different etching rates, the step of heat-treating the supporting-member-forming film to allow a plurality of the components to undergo phase separation, and the step of removing the component having a relatively higher etching rate by etching.

30. The method of producing a flat-panel display according to claim 27, wherein the supporting member constituted of a porous material member (45) is formed by a process including the step of forming a supporting-member-forming film containing a plurality of components having different etching rates and the step of removing the component having a relatively higher etching rate by etching.

31. The method of producing a flat-panel display according to claim 19, wherein the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and the first panel is produced by the steps of;

(a) forming an insulating layer (12) on a supporting substrate (10),
(b) forming a gate electrode (113) which is at least partly composed of a gas-trapping material (113B) and works as the getter, on the insulating layer (12),
(c) forming an opening portion (14) at least in the insulating layer (12), and
(d) forming or exposing an electron-emitting portion (15) in the opening portion (14).

32. The method of producing a flat-panel display according to claim 19, wherein the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and the first panel is produced by the steps of;

(a) forming an insulating layer (12) on a supporting substrate (10),
(b) forming a gate electrode (13) on the insulating layer (12),
(c) forming a second insulating layer (46) on the insulating layer (12) and the gate electrode (13),
(d) forming a focus electrode (147) which is at least partly composed of a gas-trapping material and works as the getter, on the second insulating layer (46),
(e) forming an opening portion (14) at least in the second insulating layer (46) and in the insulating layer (12), and
(f) forming or exposing an electron-emitting portion (15) in the opening portion (14).

33. The method of producing a flat-panel display according to claim 31 or 32, wherein the gate electrode has a single-layered structure composed of a gas-trapping material.

34. The method of producing a flat-panel display according to claim 31 or 32, wherein the gate electrode has a stacked structure (113) constituted, at least, of a first layer (113A) composed of an electrically conductive material or an electrically insulating material and a second layer (113B) composed of a gas-trapping material.

35. The method of producing a flat-panel display according to any one of claims 20, 21, 23, 24, 31 and 32, wherein, in the step (a), a cathode electrode (11) is formed on the supporting substrate (10) and then the insulating layer (12) is formed on the cathode electrode and the supporting substrate, and in the step of forming or exposing an electron-emitting portion in the opening portion, the electron-emitting portion (15) is formed on the cathode electrode positioned in the bottom portion of the opening portion (14).

36. The method of producing a flat-panel display according to any one of claims 20, 21, 23, 24, 31 and 32, wherein, in the step (a), an electron-emitting layer (111) is formed on the supporting substrate (10) and then the insulating layer (12) is formed on the electron-emitting layer and the supporting substrate, and in the step of forming or exposing and electron-emitting portion in the opening portion, the electron-emitting layer positioned in the bottom portion of the opening portion (14) is exposed to expose the electron-emitting portion in the opening portion.

37. The method of producing a flat-panel display according to any one of claims 20, 21, 23, 24, 31 and 32, wherein, in the step (a), the insulating layer (12) covering an electron-emitting layer (111) is formed, and in the step of forming or exposing an electron-emitting portion in the opening portion, an edge portion of the electron-emitting layer is exposed on a side wall surface of the opening portion to form the electron-emitting portion.

38. The method of producing a flat-panel display according to claim 19, wherein the first panel has cold cathode field emission devices in the effective field, the second panel has an anode electrode and a fluorescent layer in the effective field, and the first panel is produced by the steps of;

(a) disposing a spacer (12) composed of an electrically insulating material on a supporting substrate (10) and forming an electron-emitting portion (15) on the supporting substrate, and
(b) fixing a gate electrode (113) constituted of a gas-trapping material layer (113B) which has a plurality of opening portions (14) formed therein and is at least partly composed of a gas-trapping material, such that the gate electrode comes in contact with the top surface of the spacer (12) and that the opening portion is positioned above the electron-emitting portion (15).

Fig. 1A

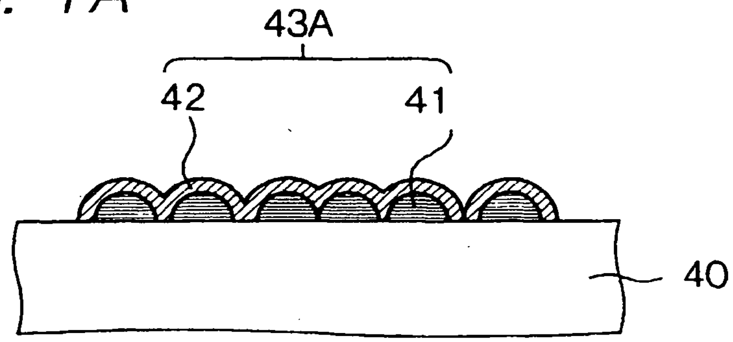


Fig. 1B

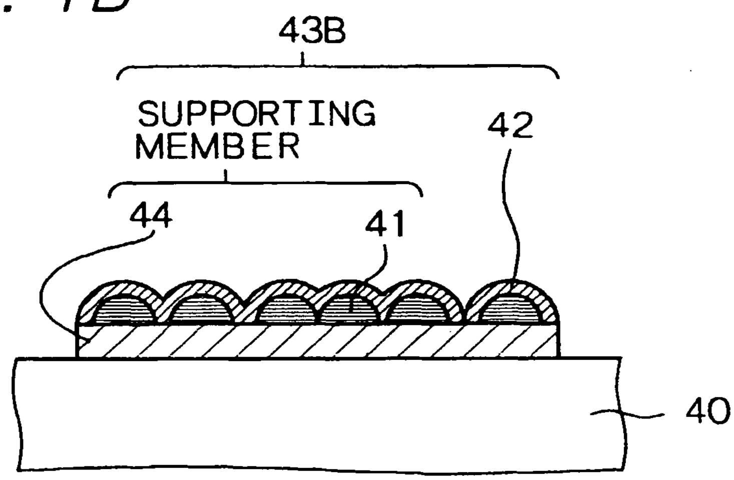


Fig. 1C

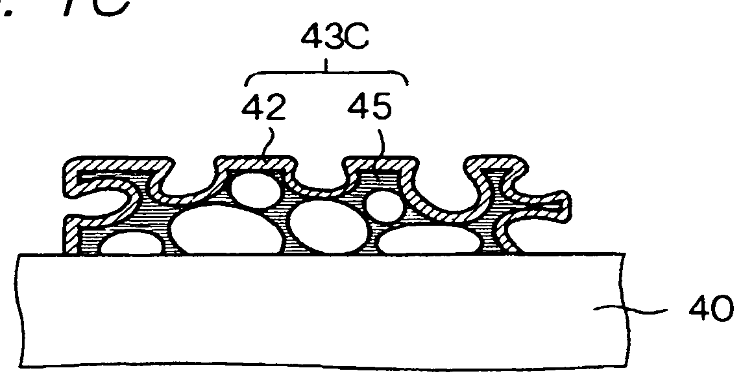


Fig. 2A

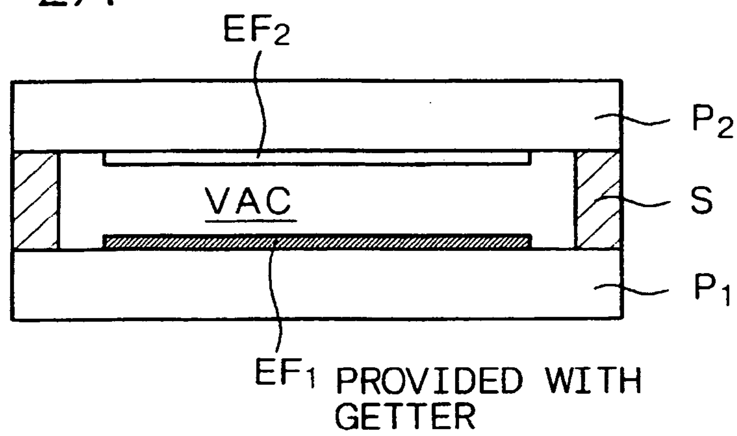


Fig. 2B

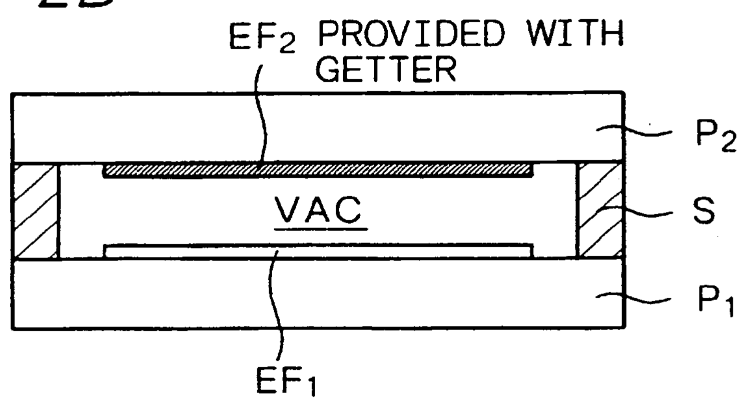


Fig. 2C

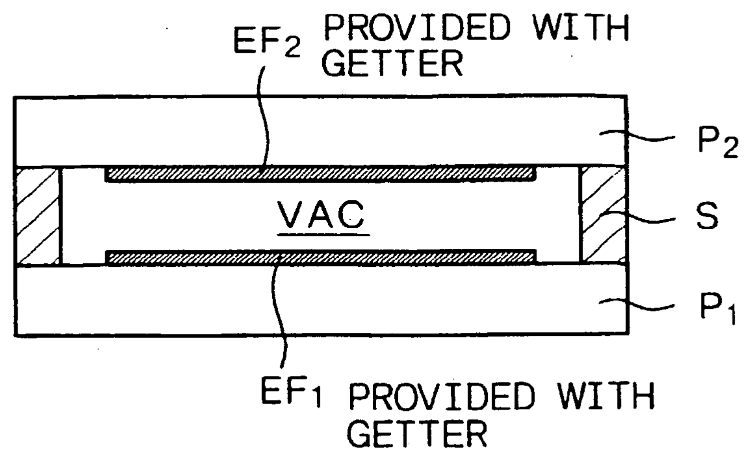


Fig. 3A

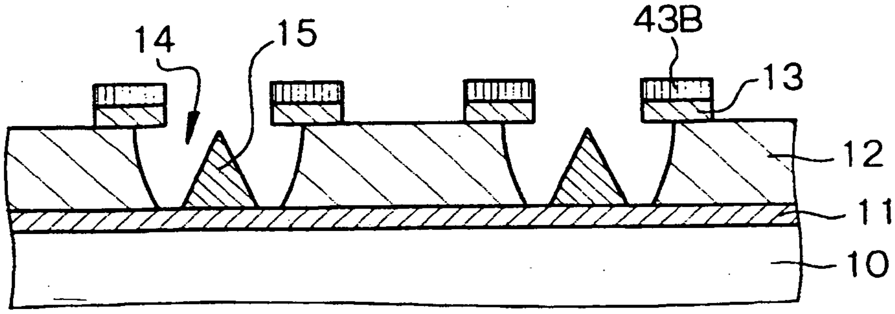


Fig. 3B

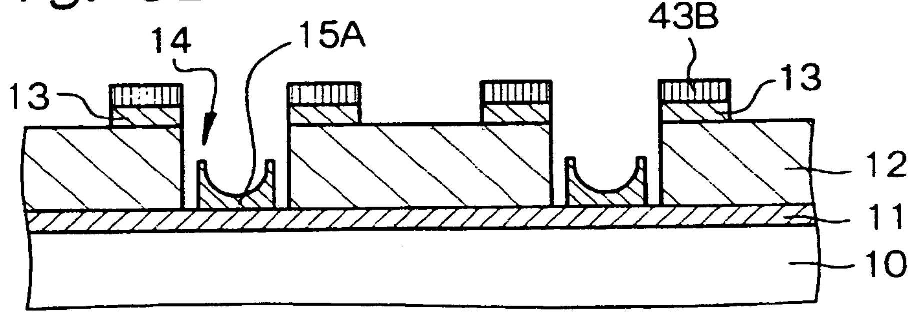


Fig. 3C

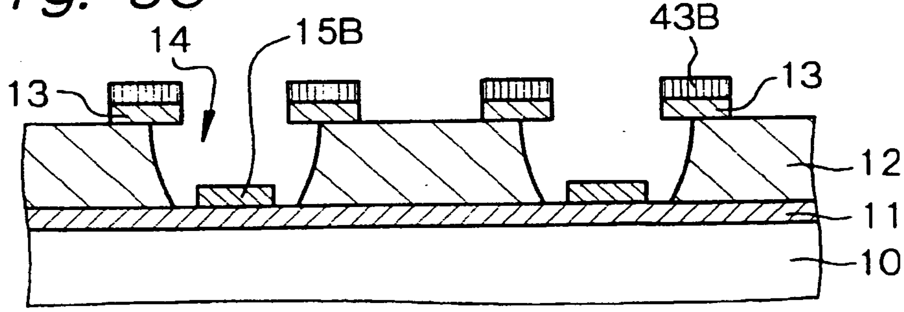


Fig. 3D

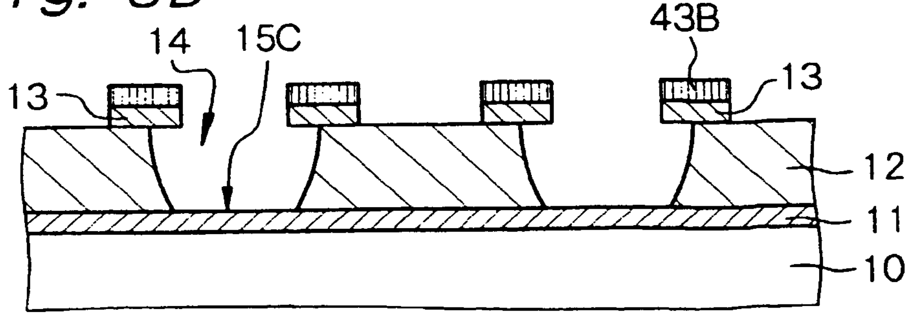


Fig. 4A

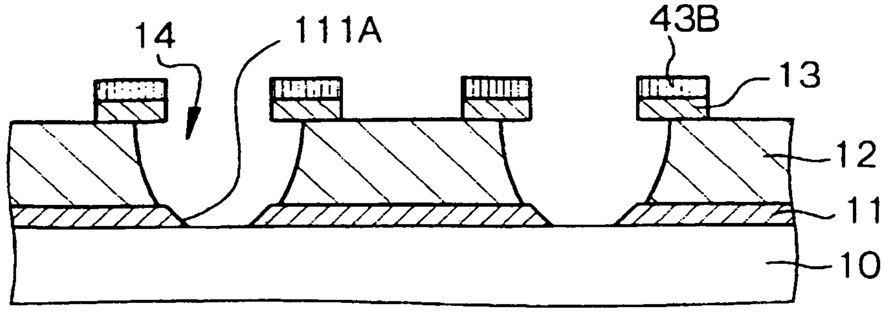


Fig. 4B

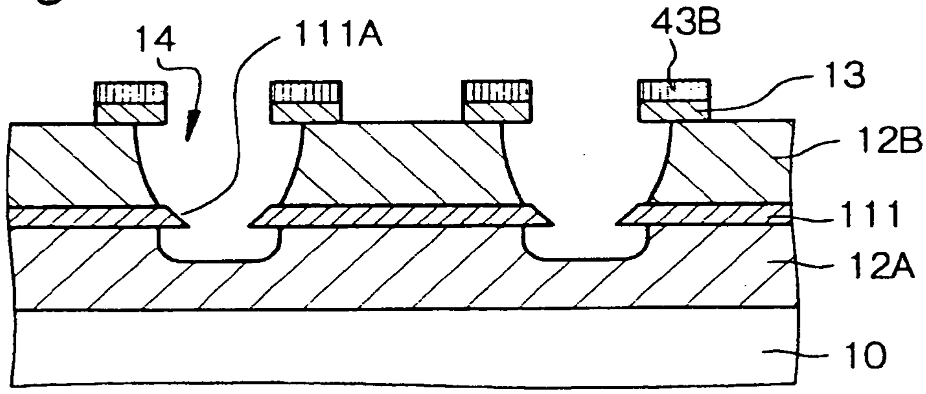


Fig. 4C

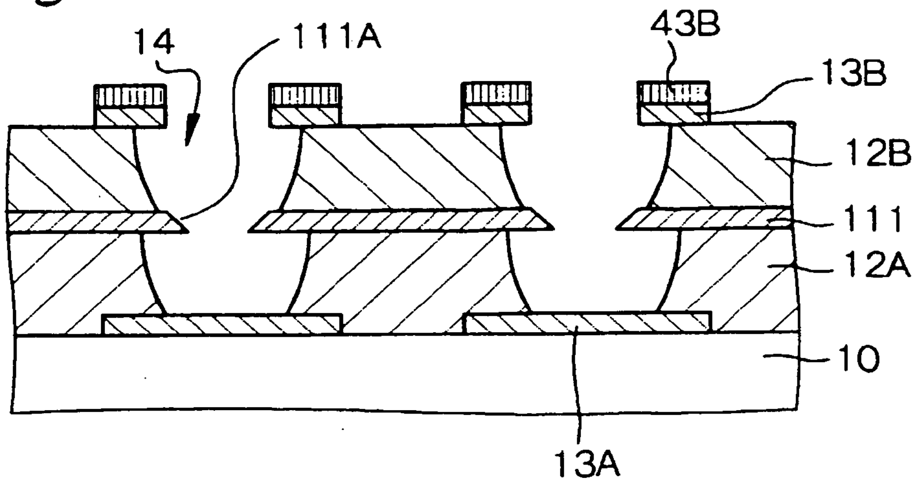


Fig. 5A

[STEP-200]

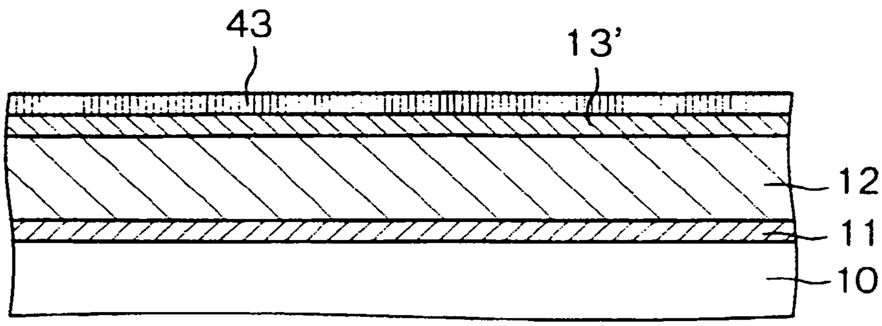


Fig. 5B

[STEP-210]

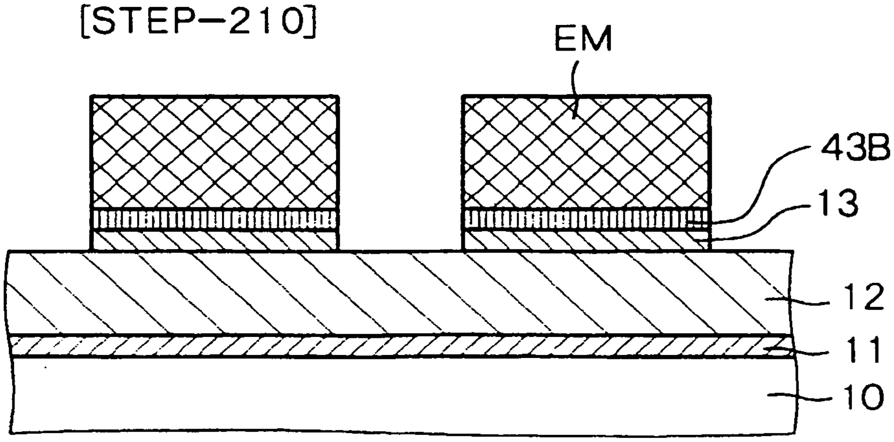


Fig. 6A

[STEP–220]

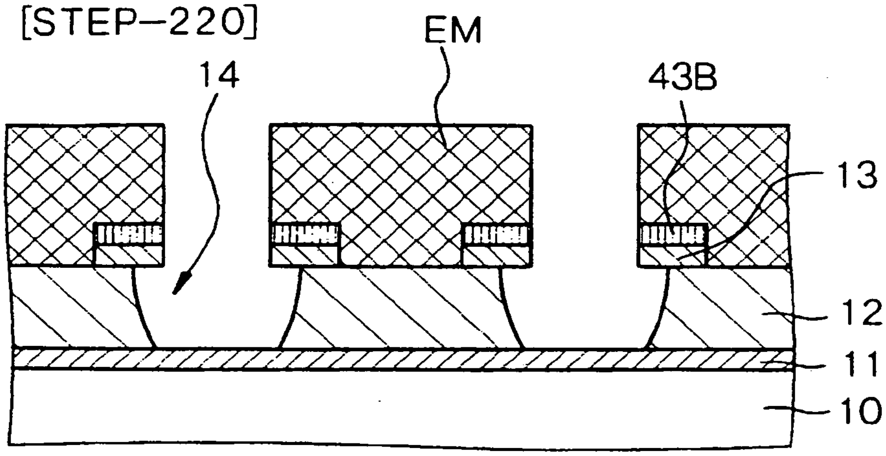


Fig. 6B

[STEP–230]

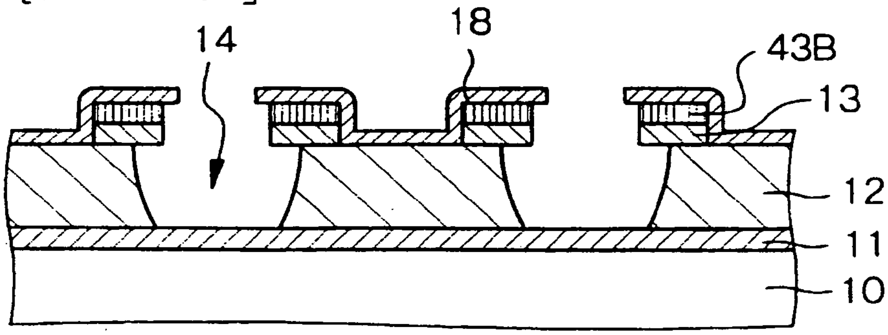


Fig. 7A

[STEP-240]

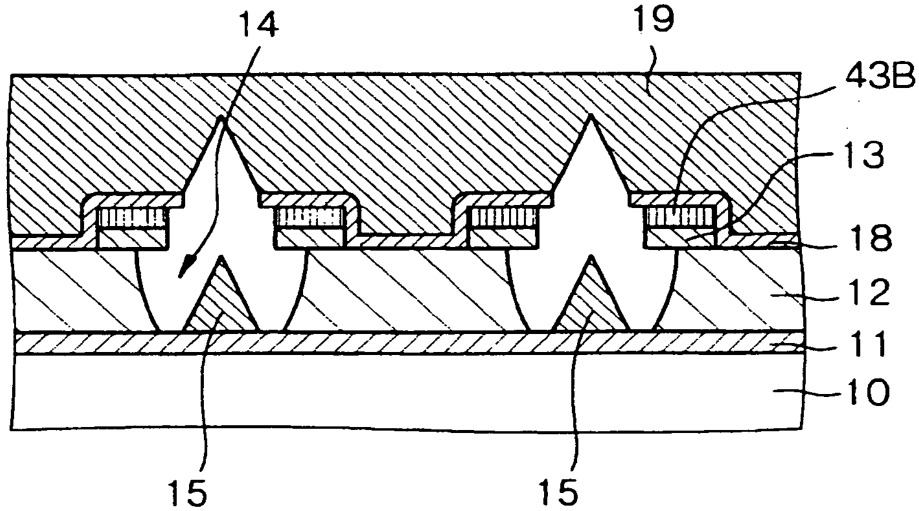


Fig. 7B

[STEP-250]

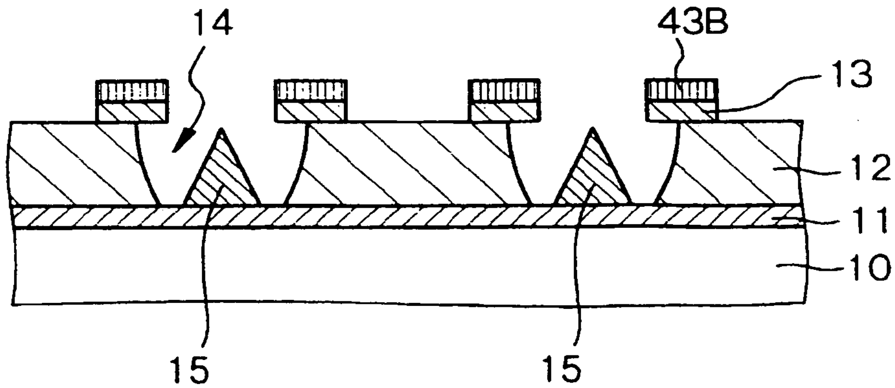


Fig. 8A

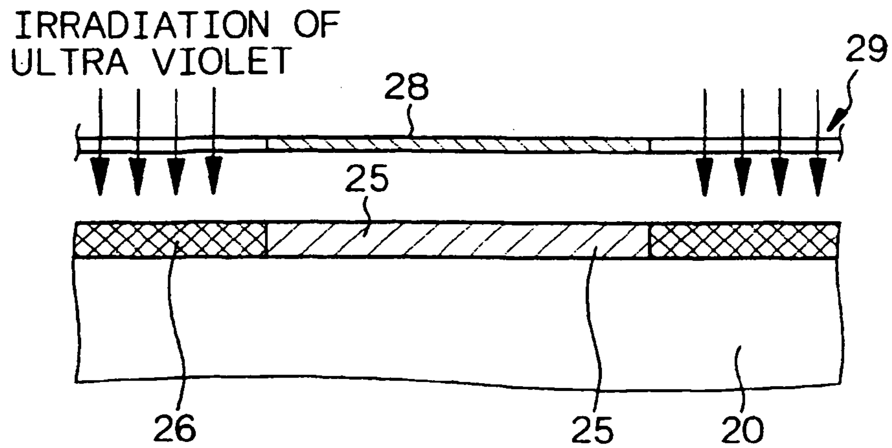


Fig. 8B

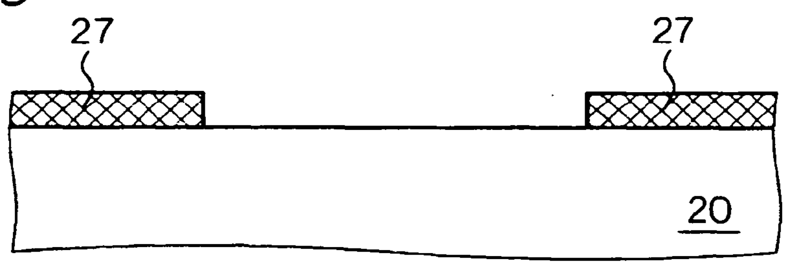


Fig. 8C

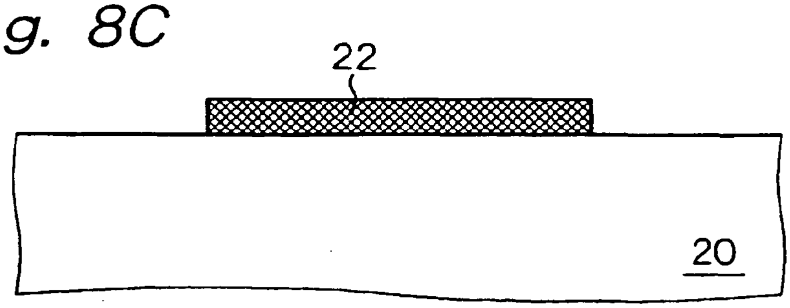
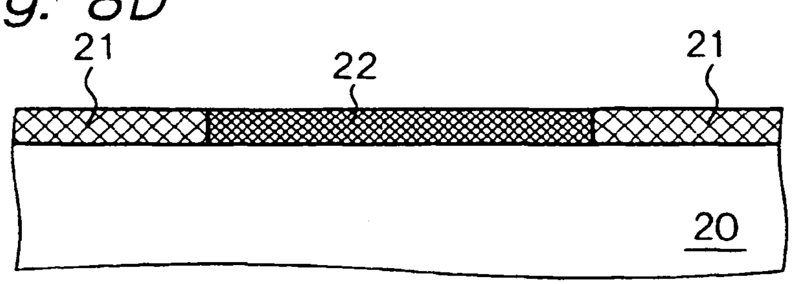


Fig. 8D



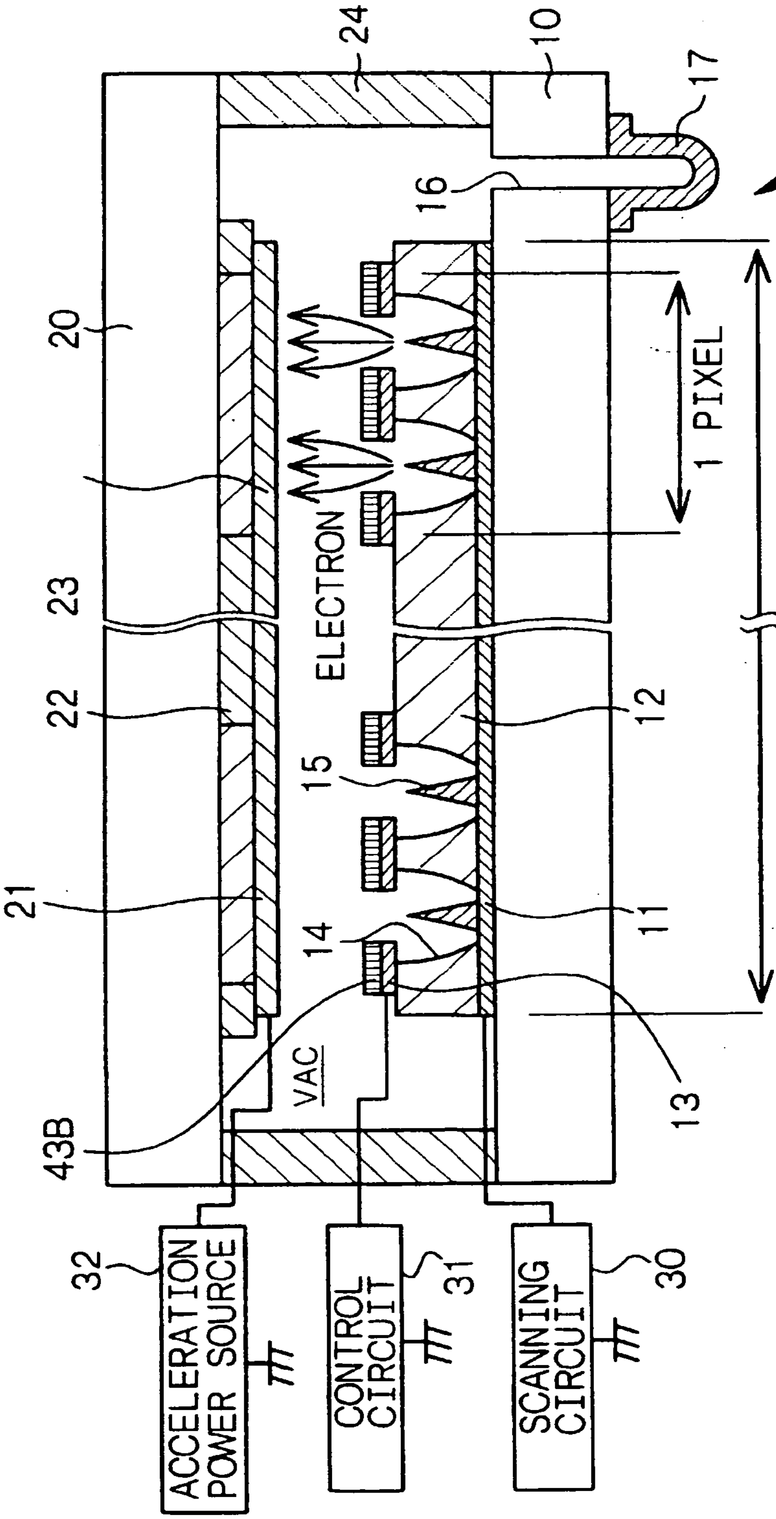

20
24
10
17
16
P1
P2
23
22
21
43B
14
15
12
11
13
ELECTRON
VAC
1 PIXEL
EF1
ACCELERATION POWER SOURCE
32
CONTROL CIRCUIT
31
SCANNING CIRCUIT
30

Fig. 9

Fig. 10

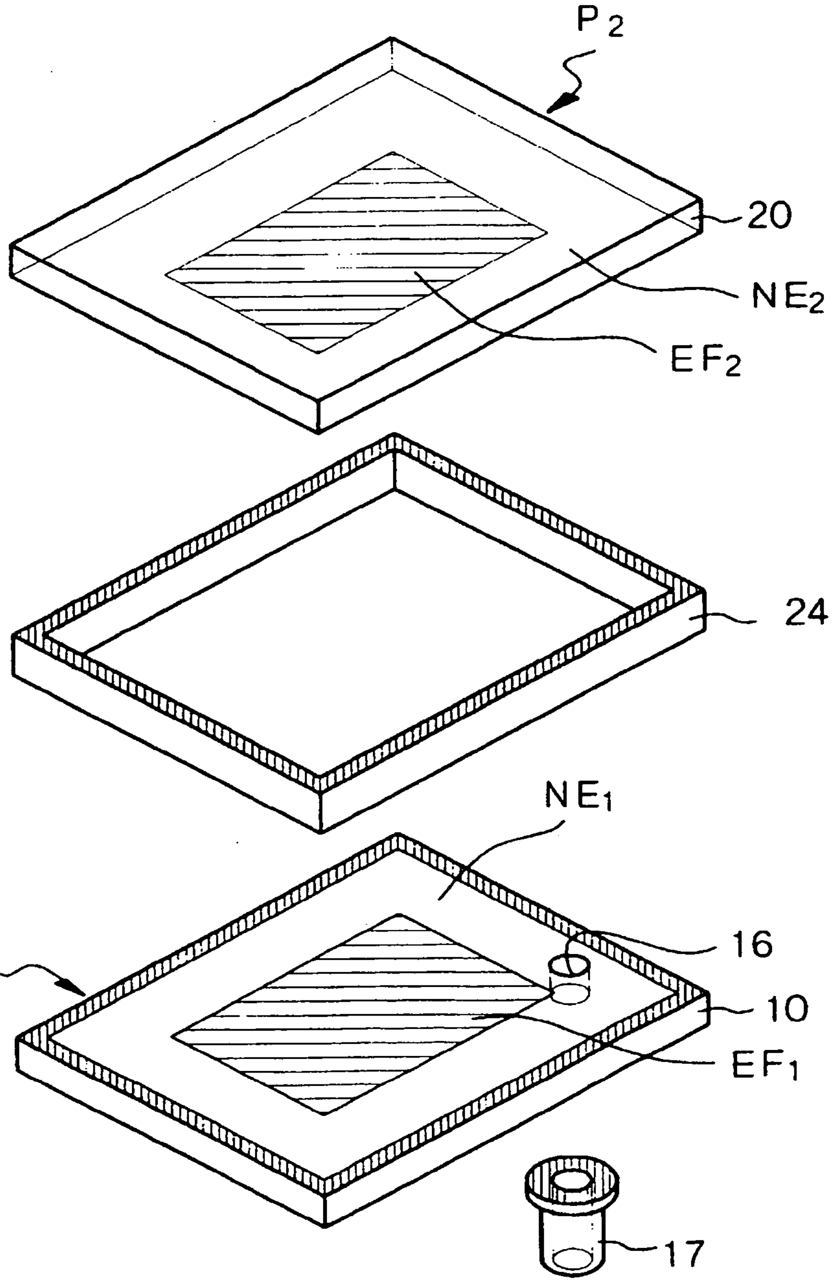


Fig. 11

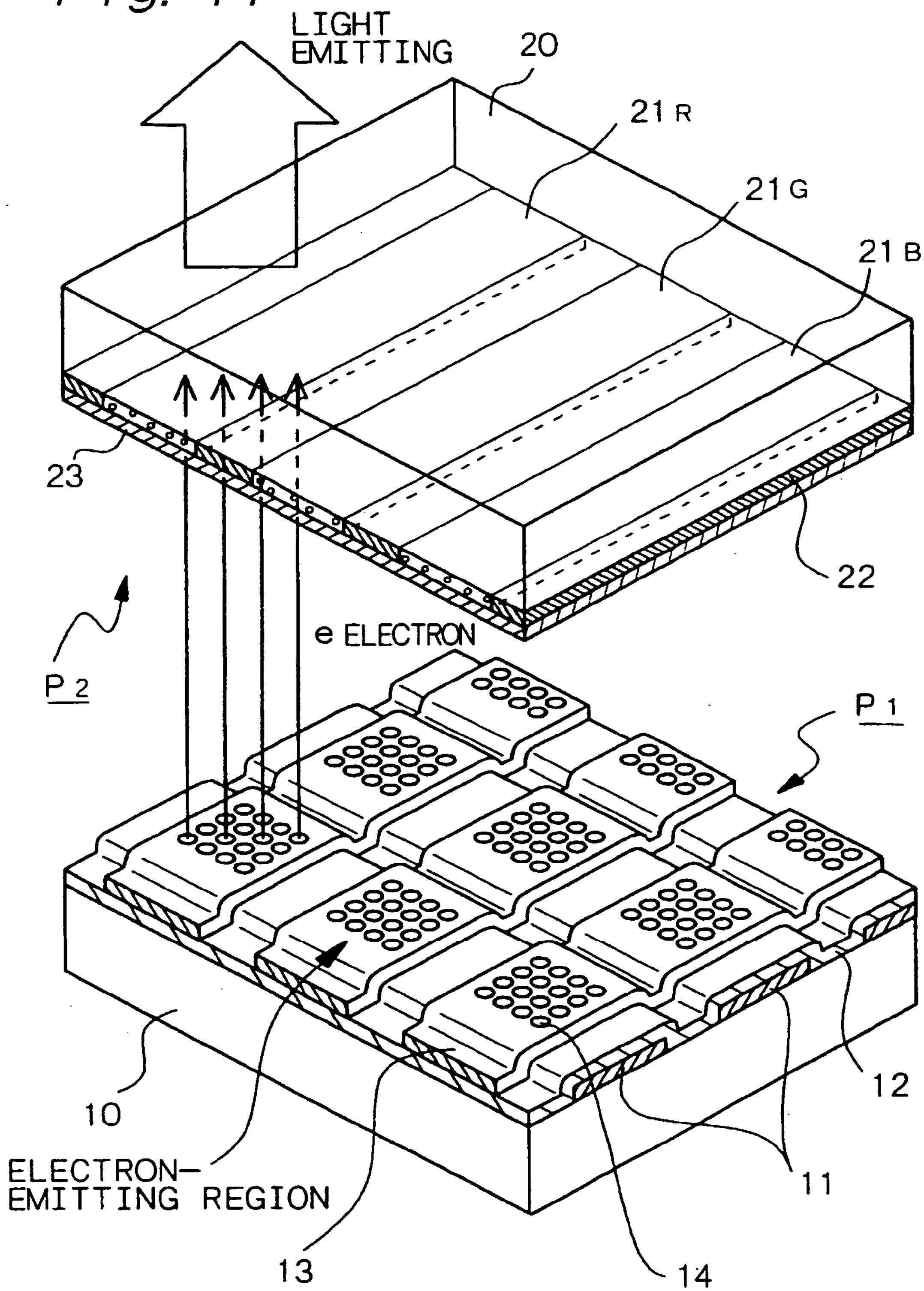

LIGHT EMITTING
20
21 R
21 G
21 B
23
22
P 2
e ELECTRON
P 1
12
10
11
ELECTRON-EMITTING REGION
13
14

Fig. 12A

[STEP—600]

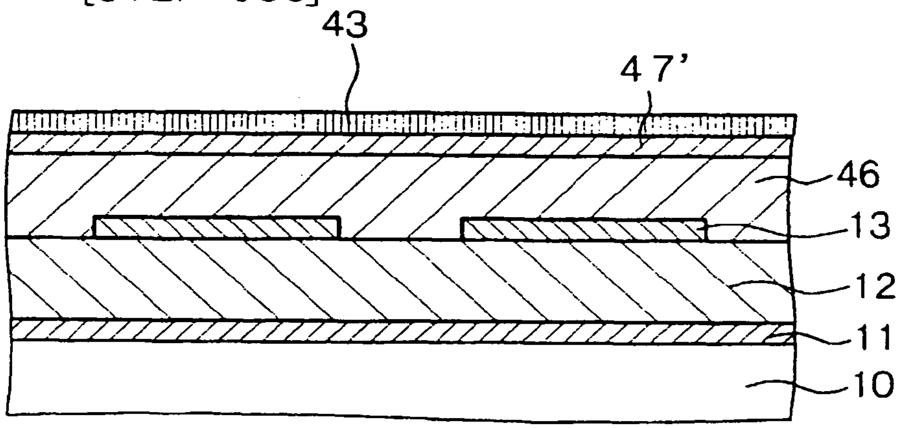


Fig. 12B

[STEP—610]

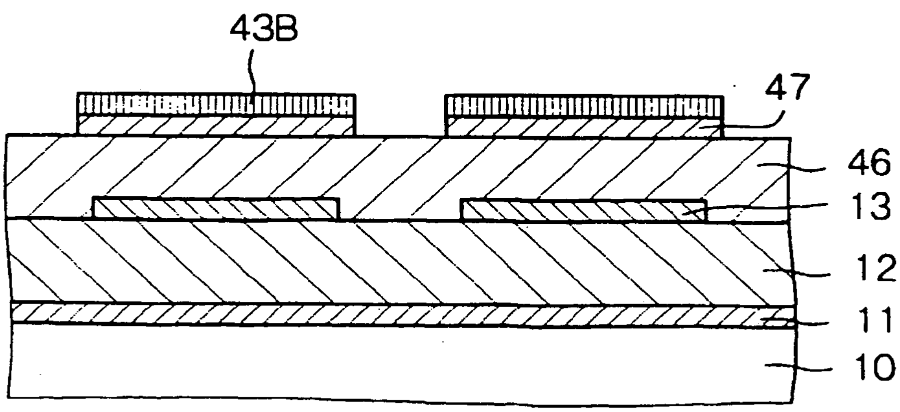


Fig. 13A

[STEP–620]

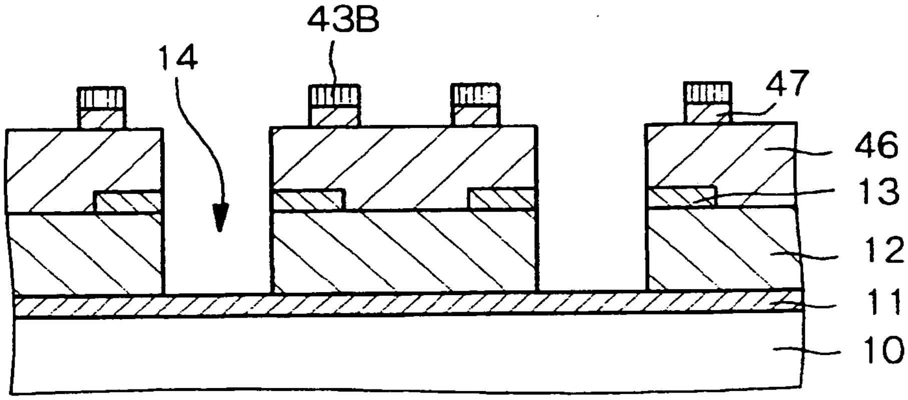


Fig. 13B

[STEP–630]

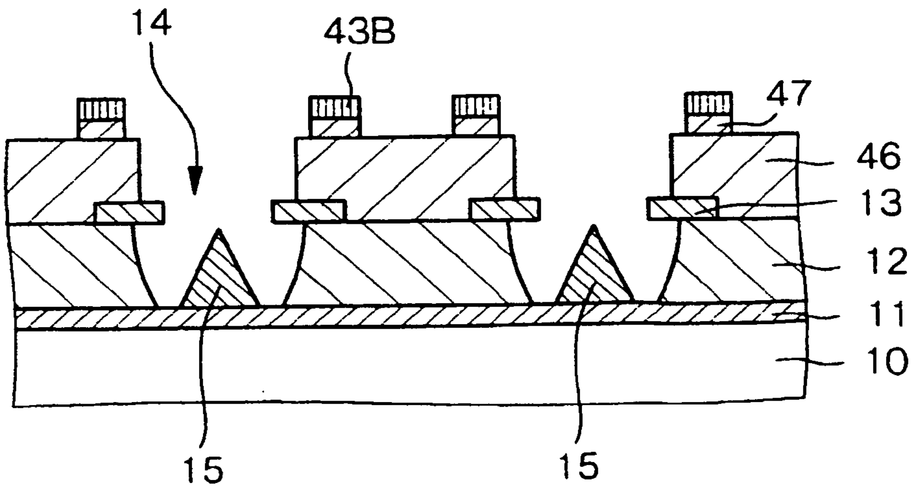


Fig. 14A

[STEP–700]

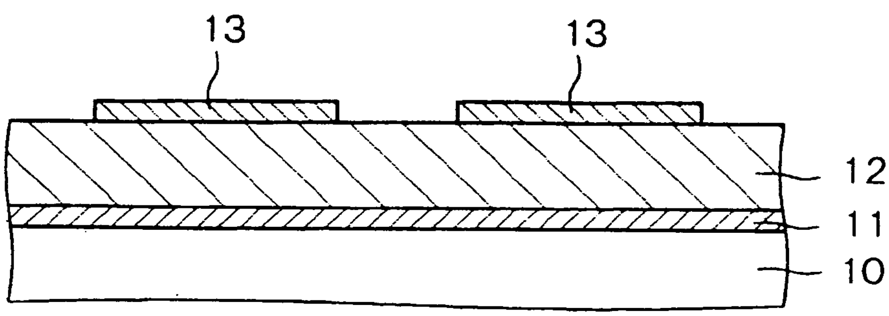


Fig. 14B

[STEP–710]

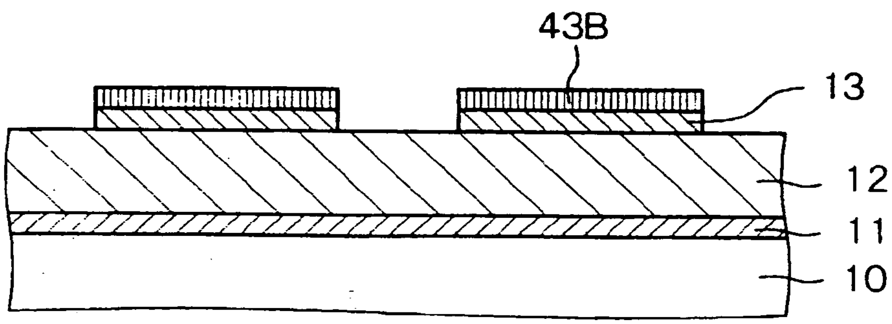


Fig. 15A

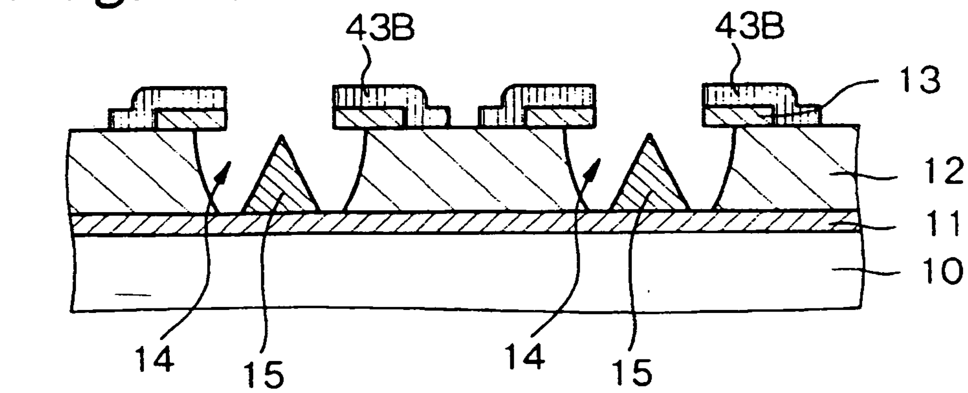


Fig. 15B

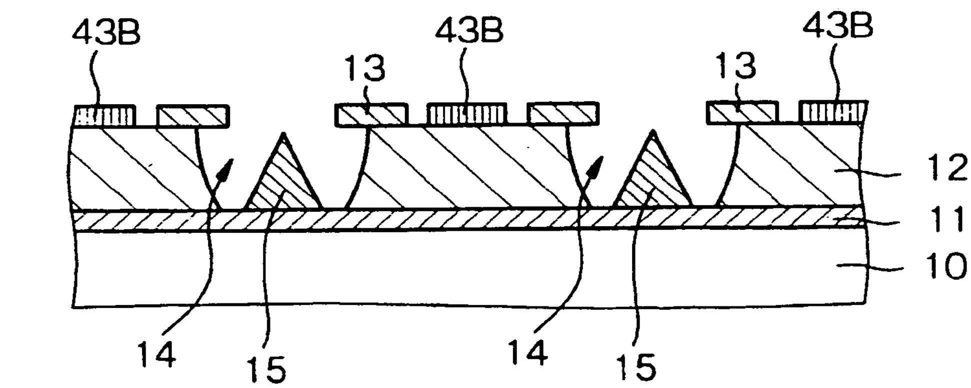


Fig. 15C

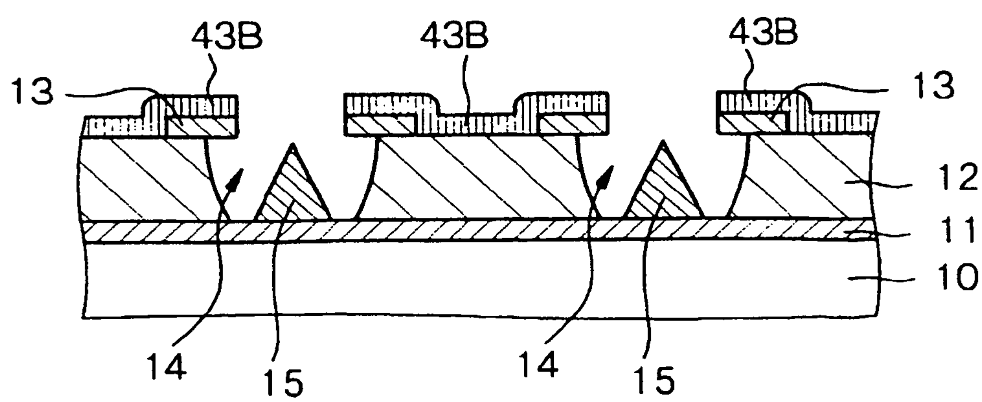


Fig. 16A

[STEP–800]

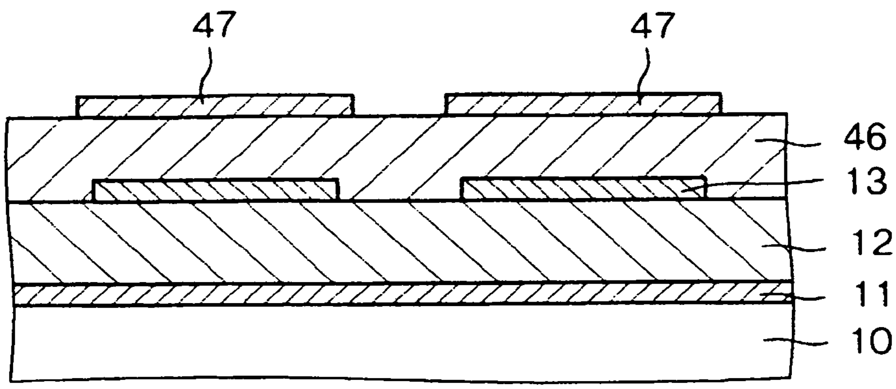


Fig. 16B

[STEP–810]

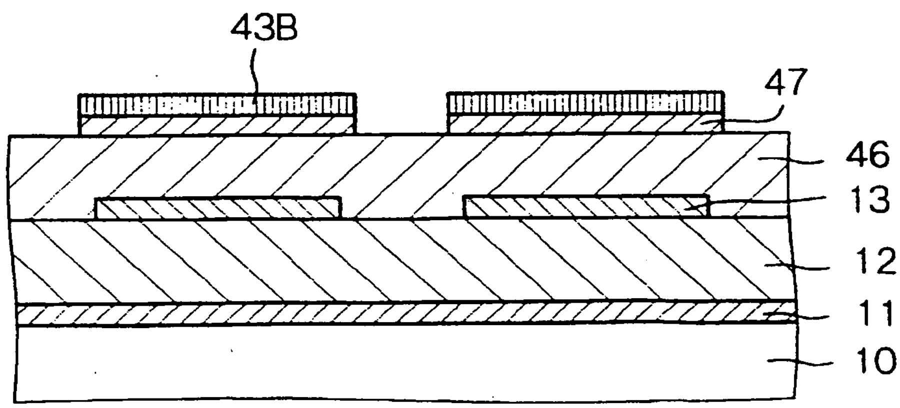


Fig. 17A

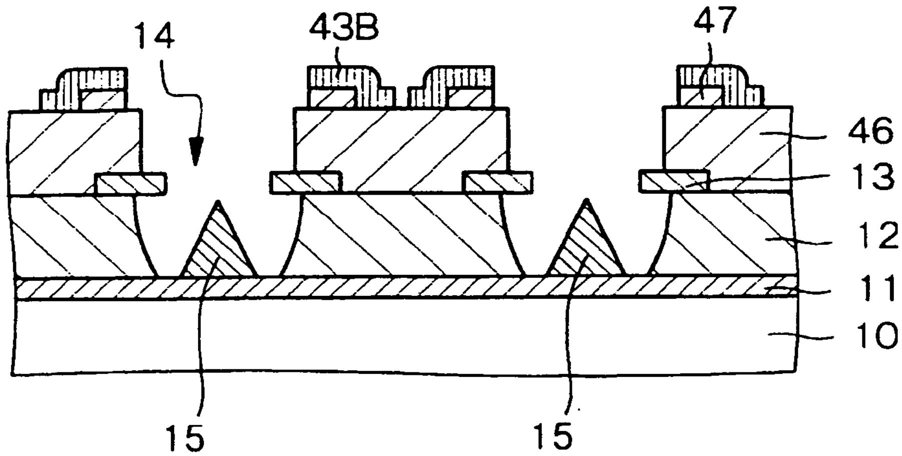


Fig. 17B

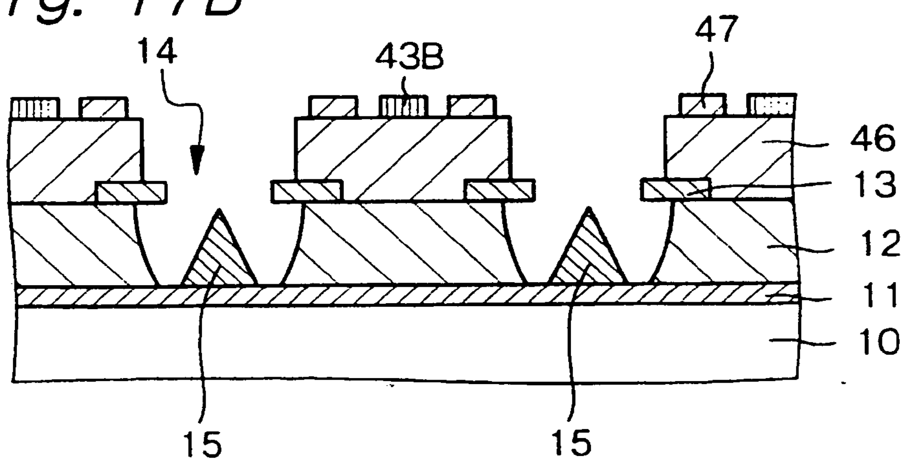


Fig. 17C

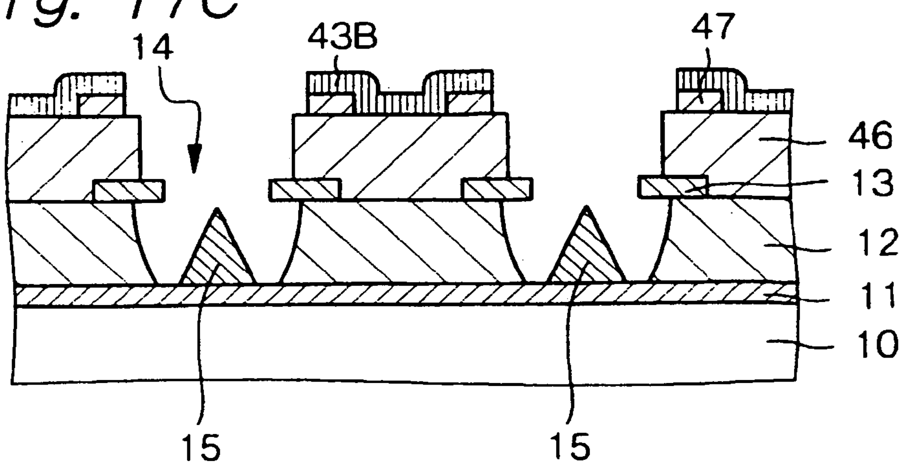


Fig. 18A

[STEP–900]

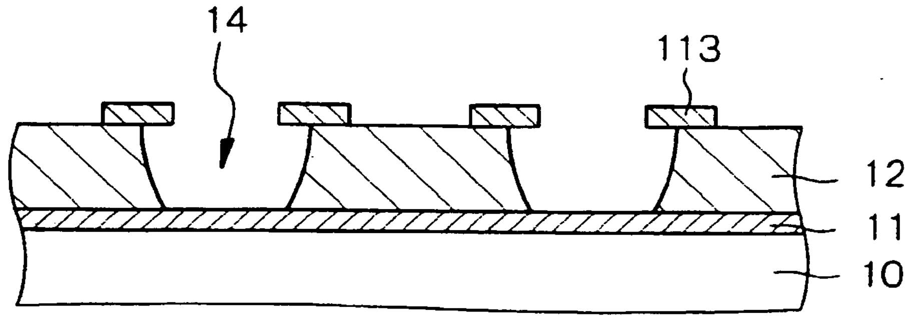


Fig. 18B

[STEP–910]

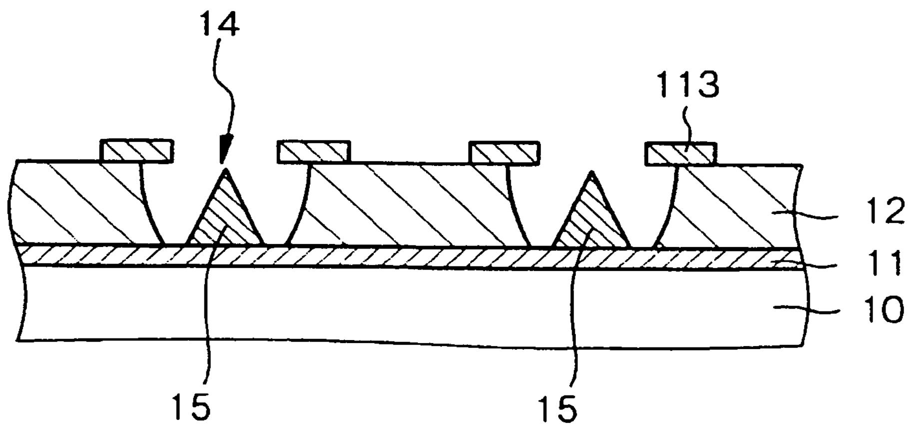


Fig. 19A

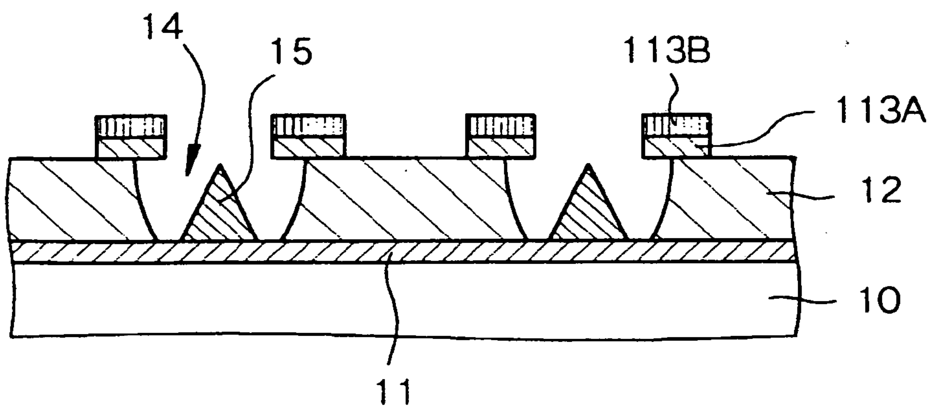


Fig. 19B

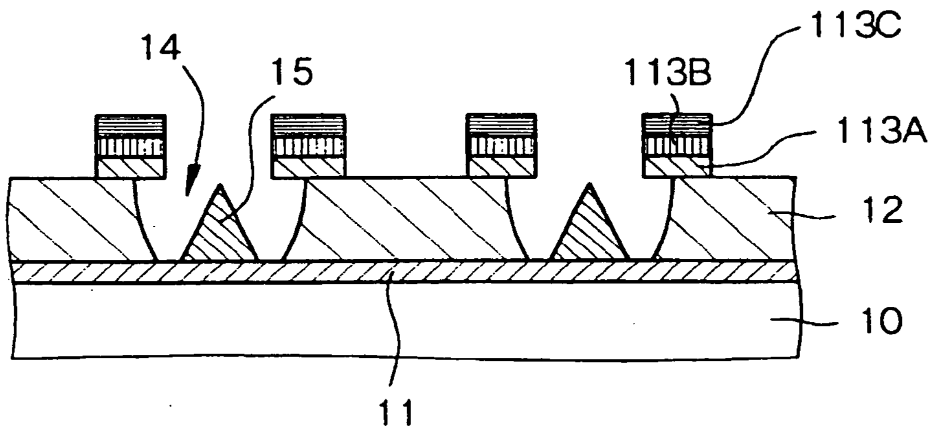


Fig. 20A

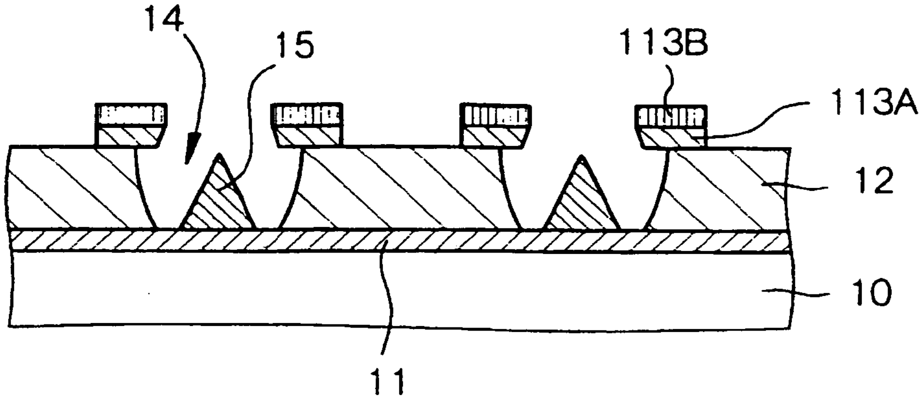


Fig. 20B

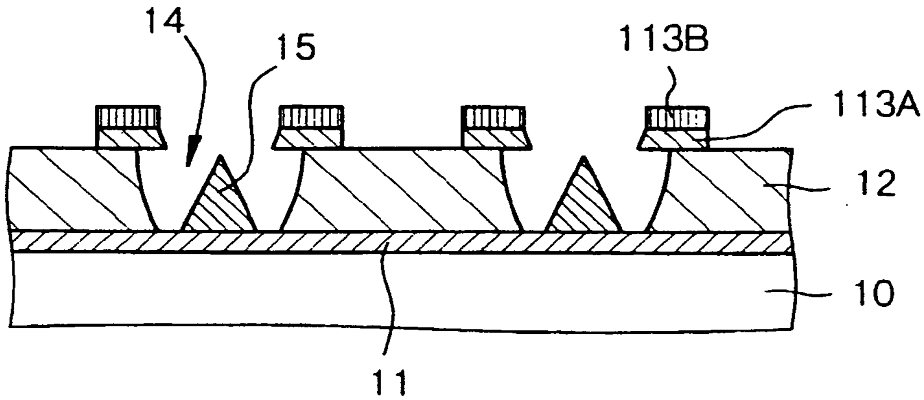


Fig. 20C

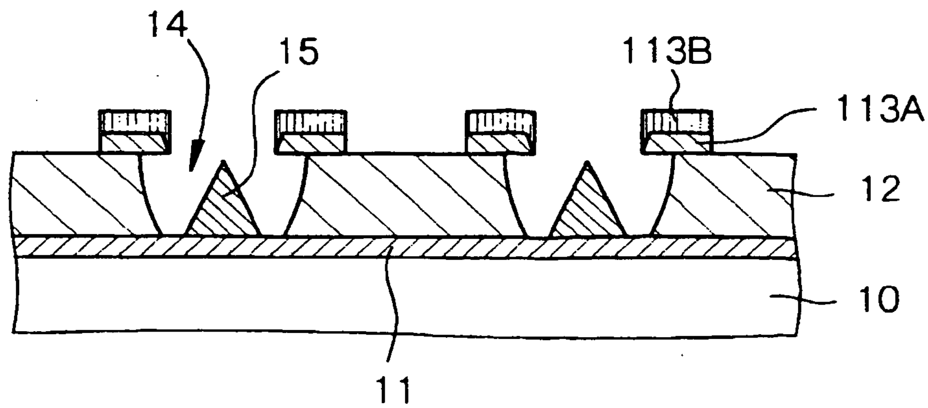


Fig. 21A

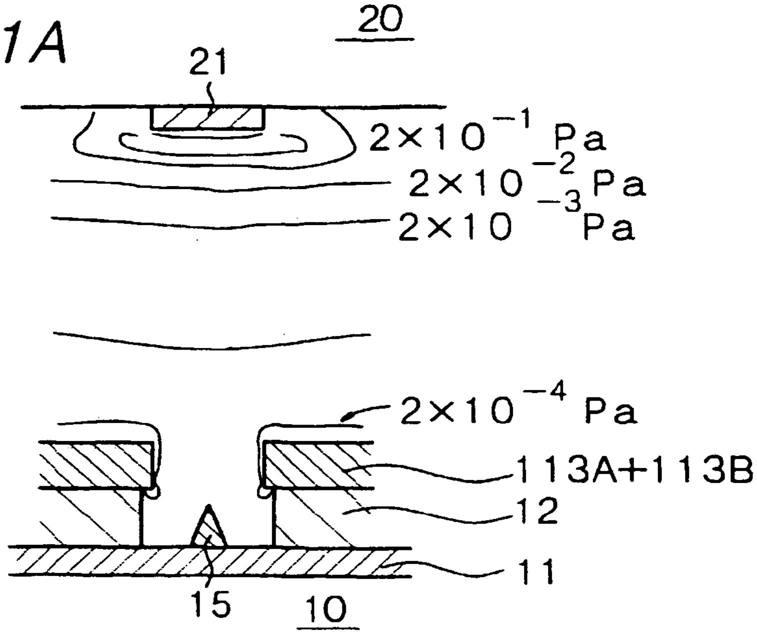


Fig. 21B

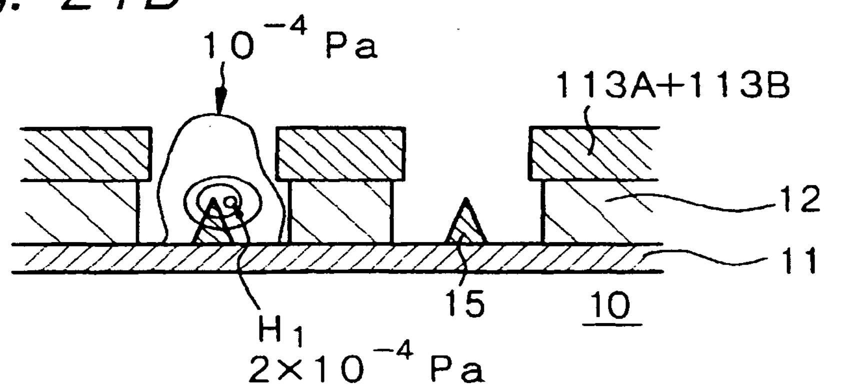


Fig. 21C

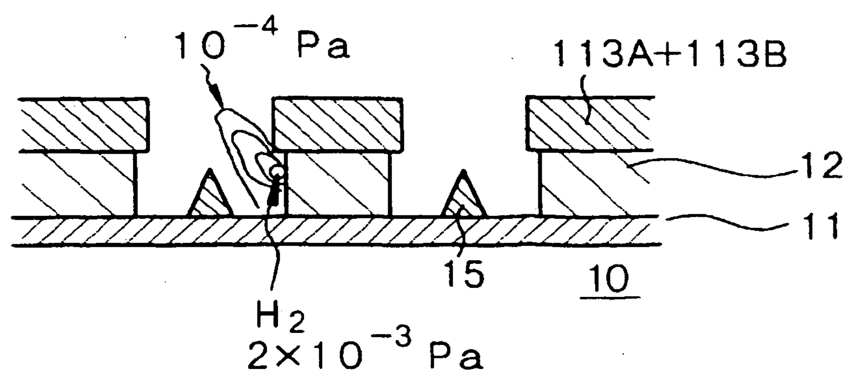


Fig. 22A

[STEP-1000]

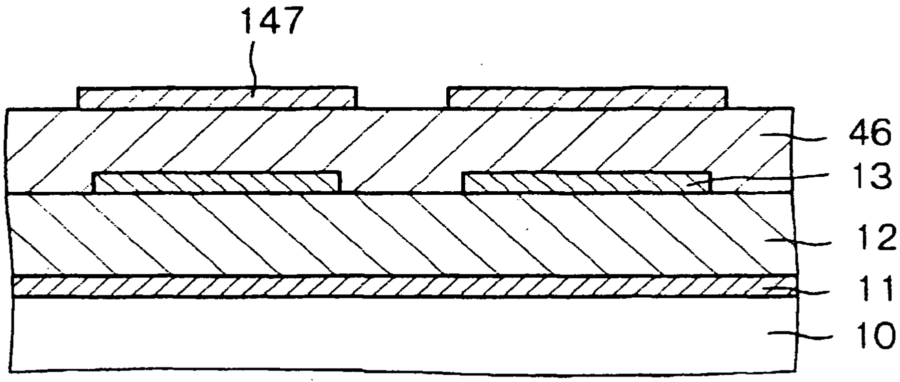


Fig. 22B

[STEP-1010]

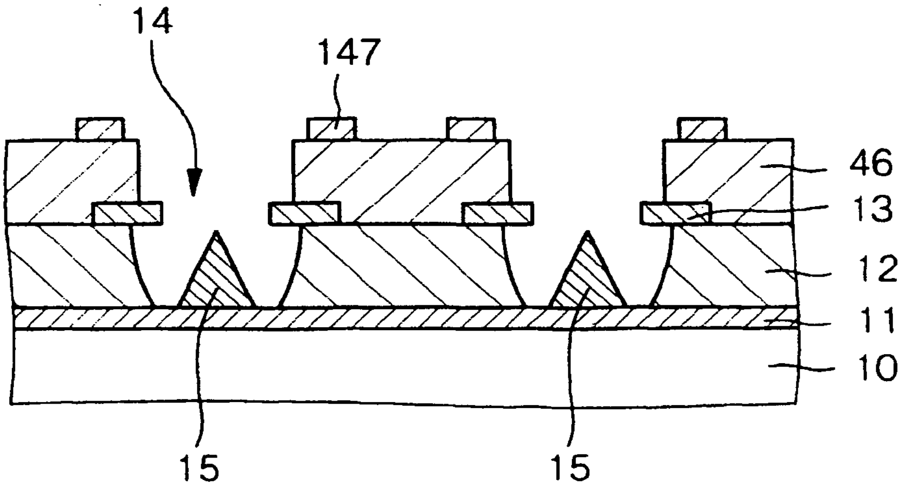


Fig. 23

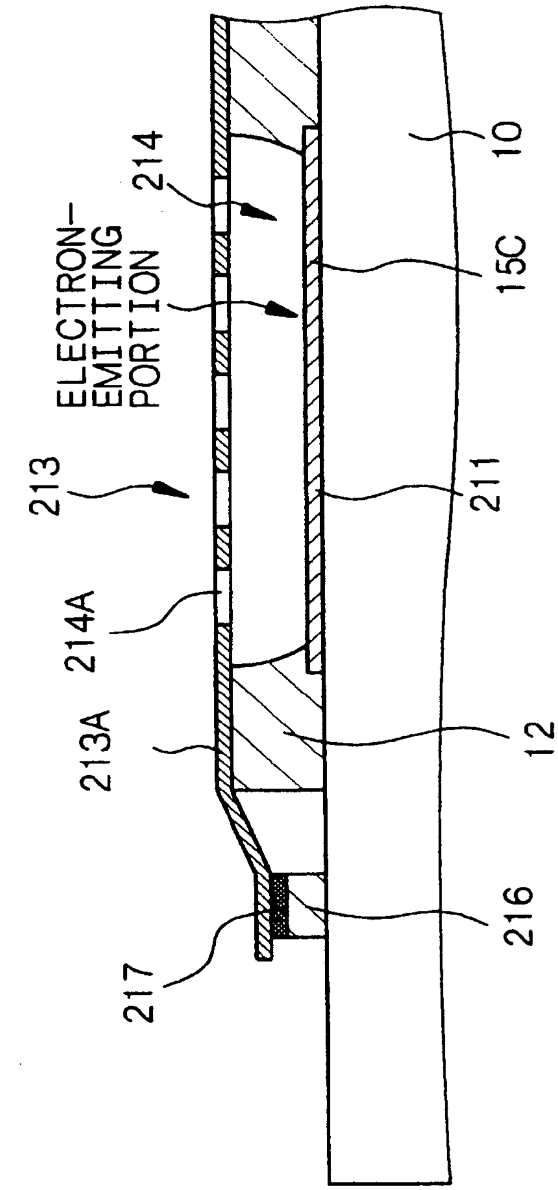

214
ELECTRON-
EMITTING
PORTION
213
214A
213A
217
216
12
211
15C
10

Fig. 24

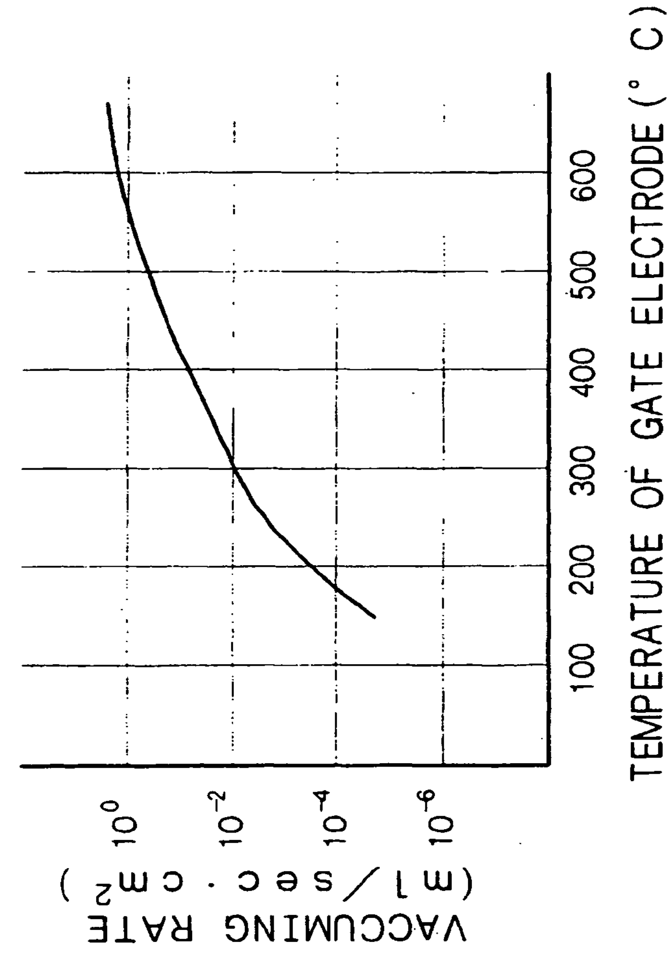

VACCUMING RATE
(ml/sec·cm^2)
10^0
10^{-2}
10^{-4}
10^{-6}
100
200
300
400
500
600
TEMPERATURE OF GATE ELECTRODE (° C)

Fig. 25A

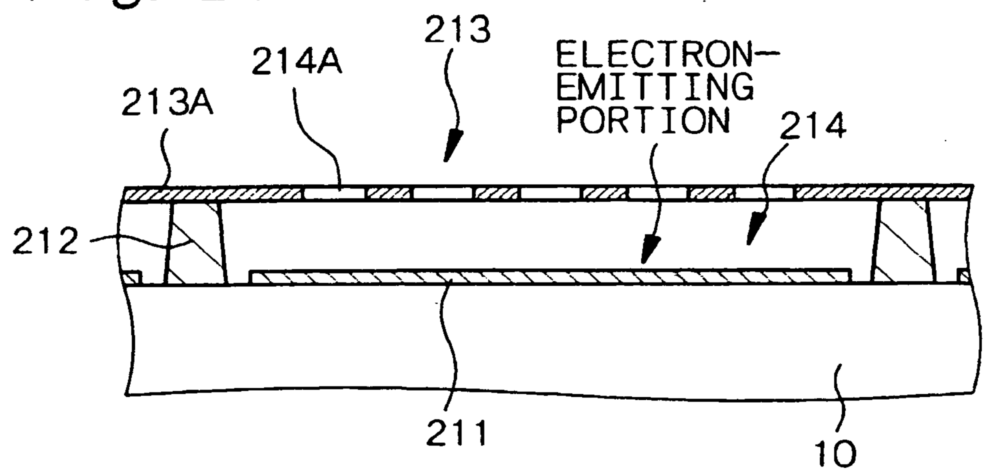


Fig. 25B

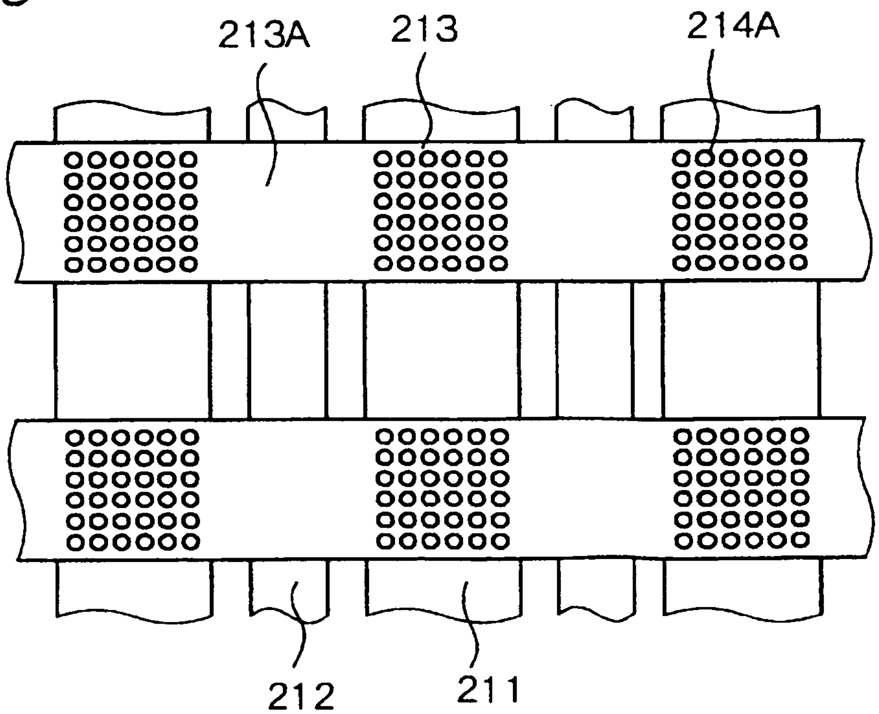


Fig. 26A

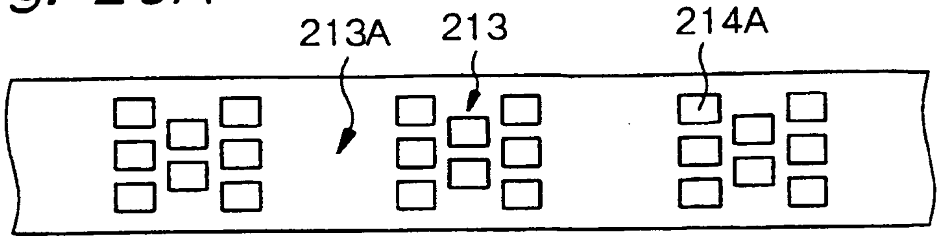


Fig. 26B

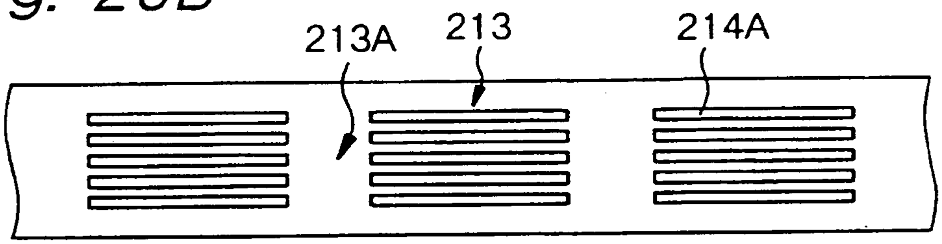


Fig. 26C

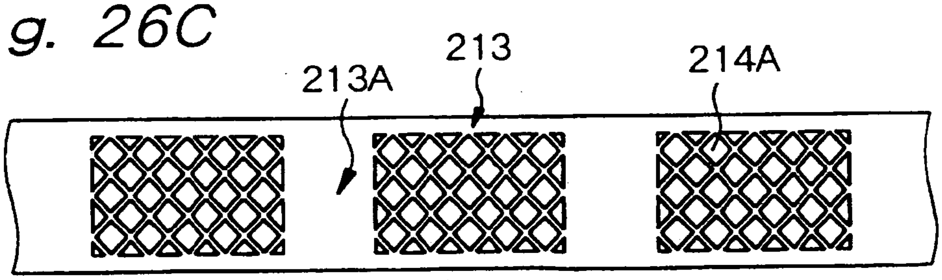


Fig. 26D

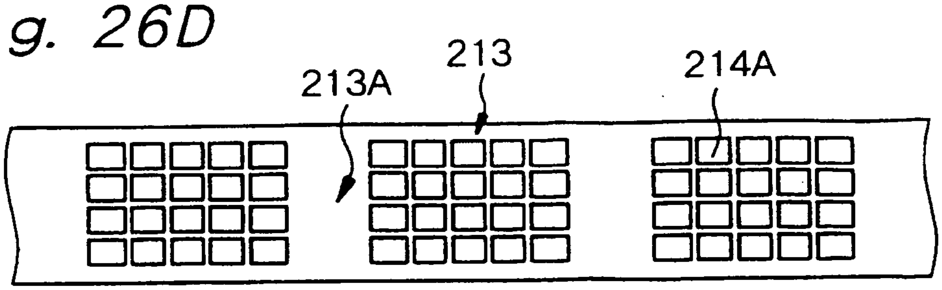


Fig. 27A

[STEP-1300]

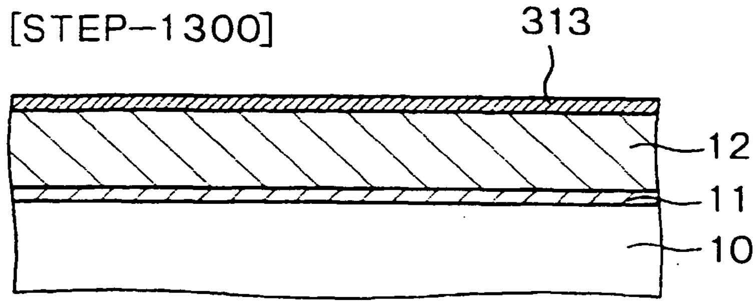


Fig. 27B

[STEP-1310]

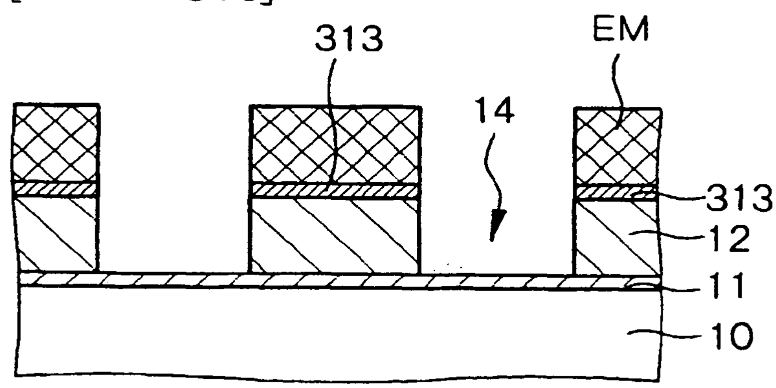


Fig. 28A

[STEP–1320]

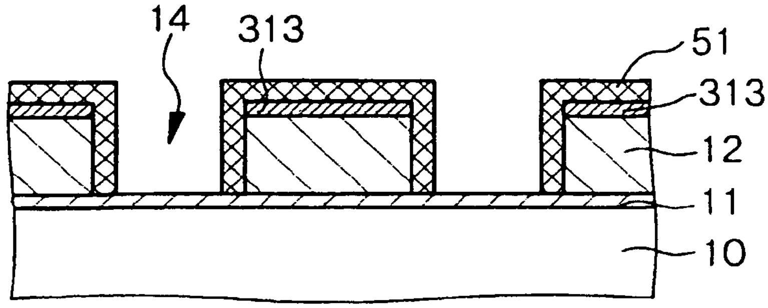


Fig. 28B

[STEP–1330]

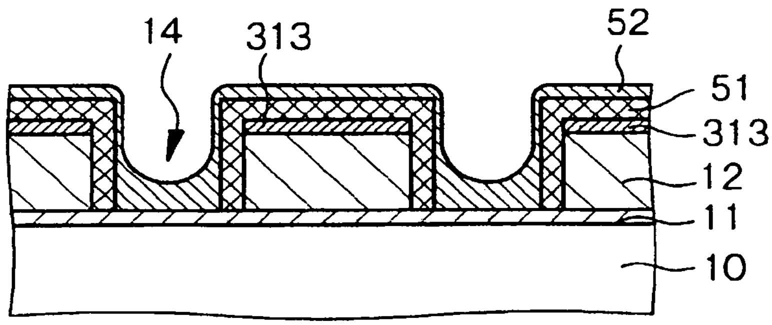


Fig. 28C

[STEP–1340]

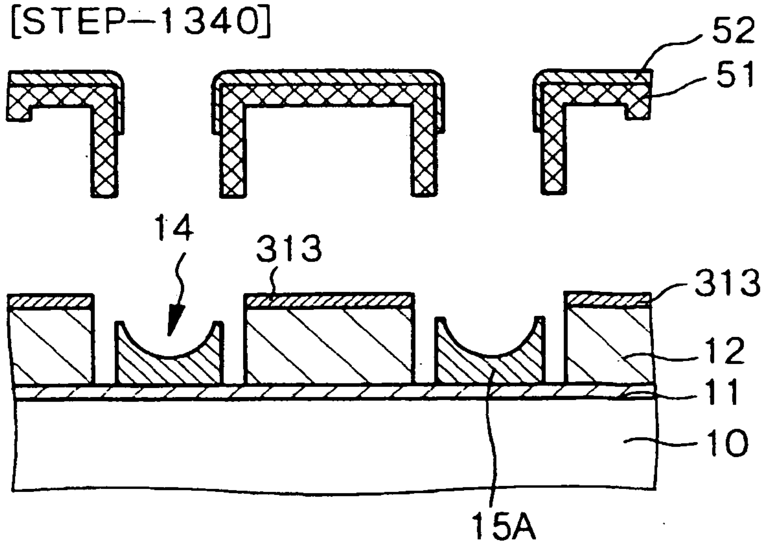


Fig. 29A

[STEP−1340]

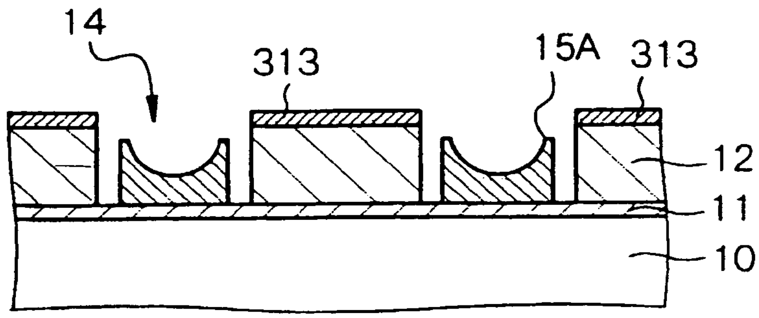


Fig. 29B

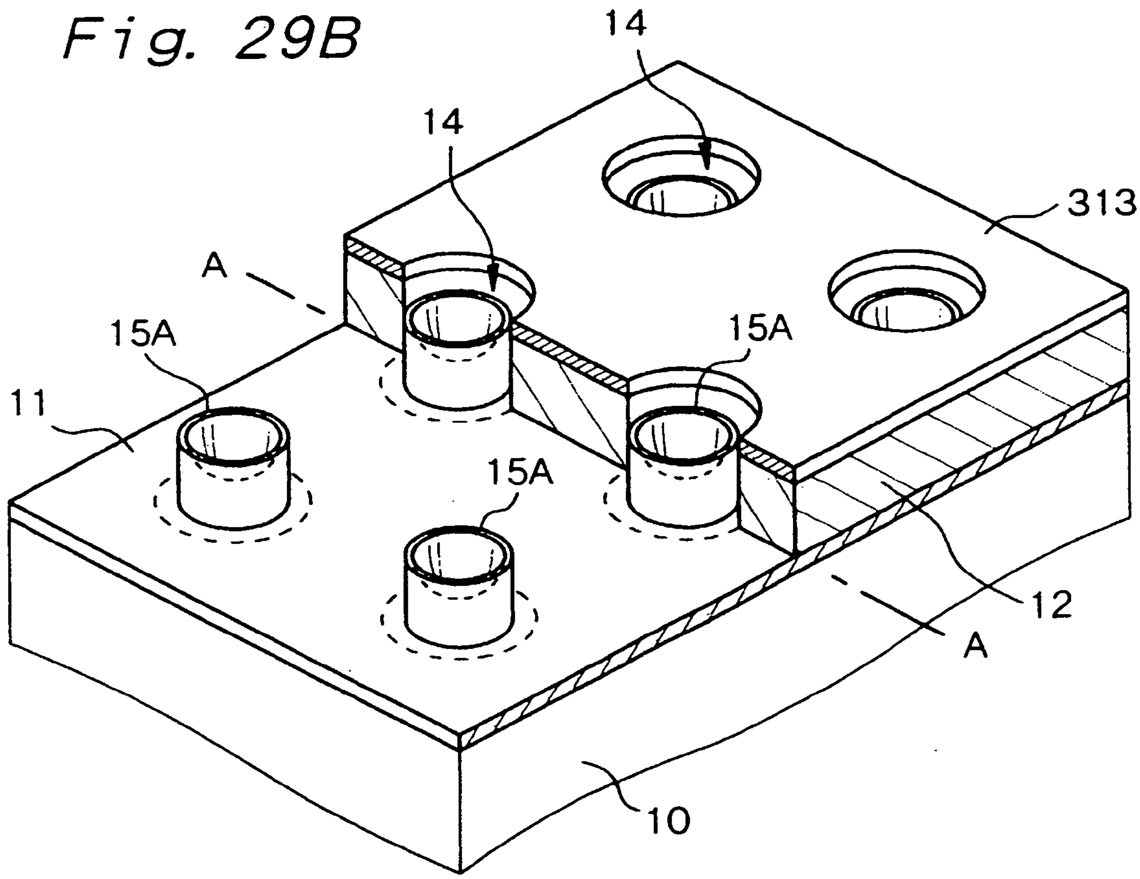


Fig. 30A

[STEP-1400]

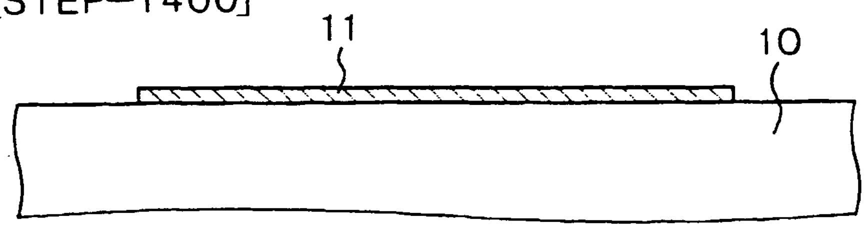


Fig. 30B

[STEP-1410]

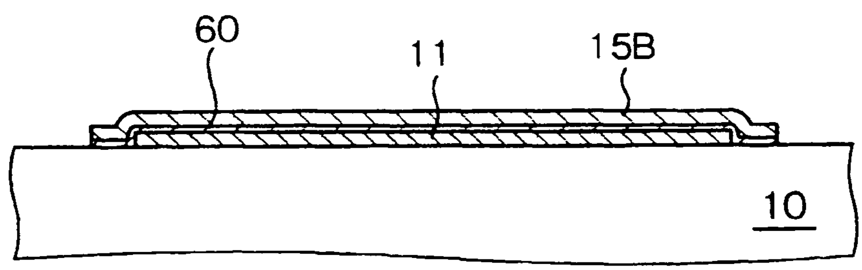


Fig. 30C

[STEP-1430]

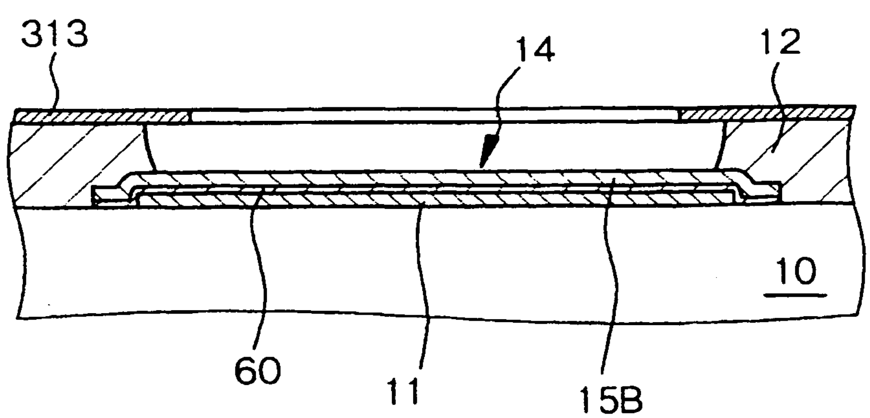


Fig. 31A

[STEP-1500]

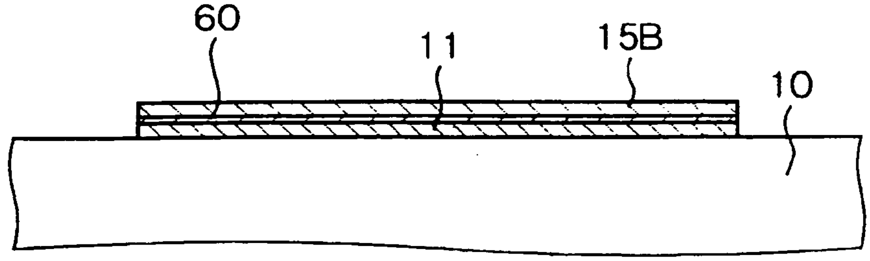


Fig. 31B

[STEP-1510]

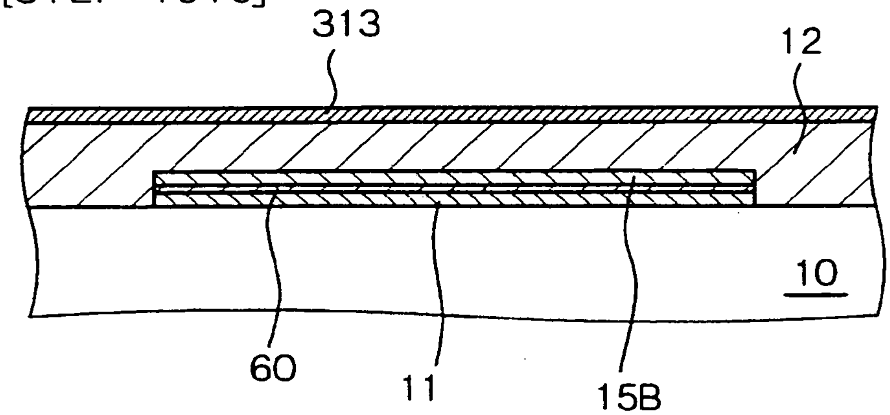


Fig. 31C

[STEP-1510] CONTINUED

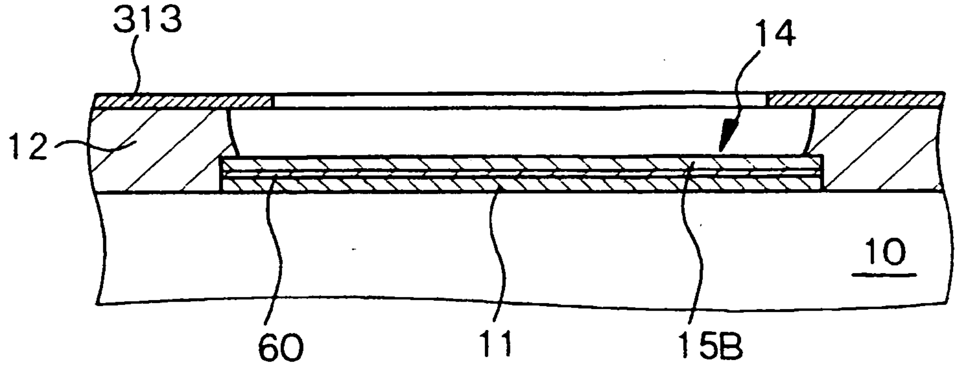


Fig. 32A

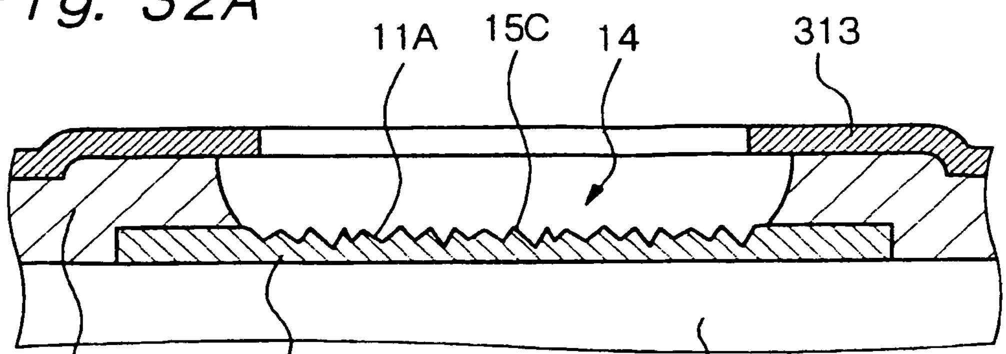


Fig. 32B

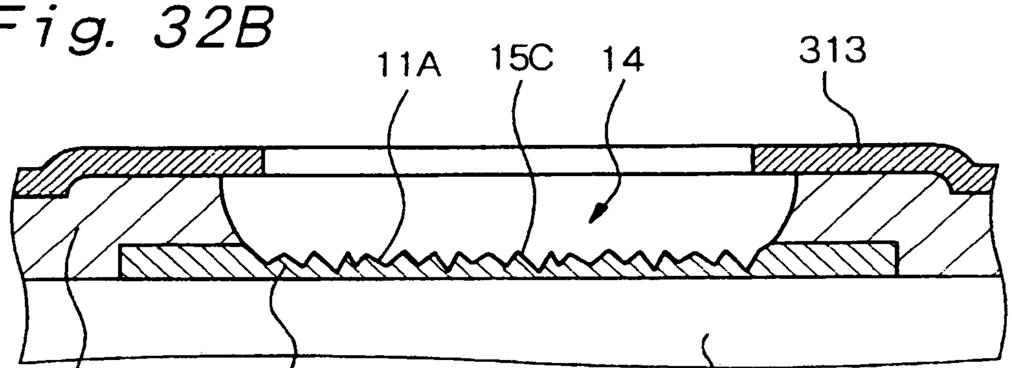


Fig. 33

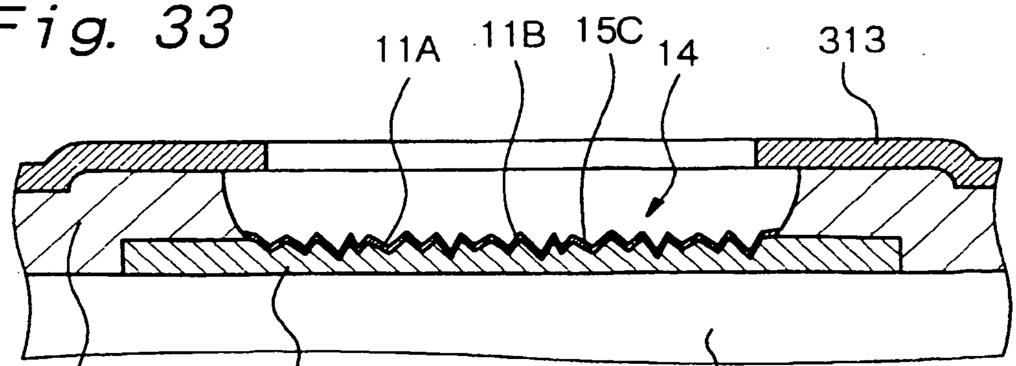


Fig. 34A

[STEP–1700]

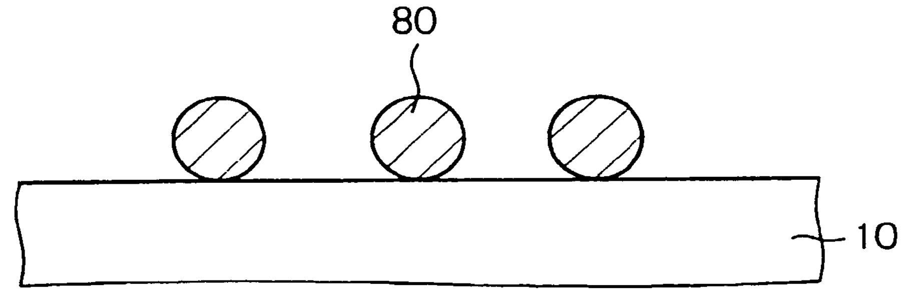


Fig. 34B

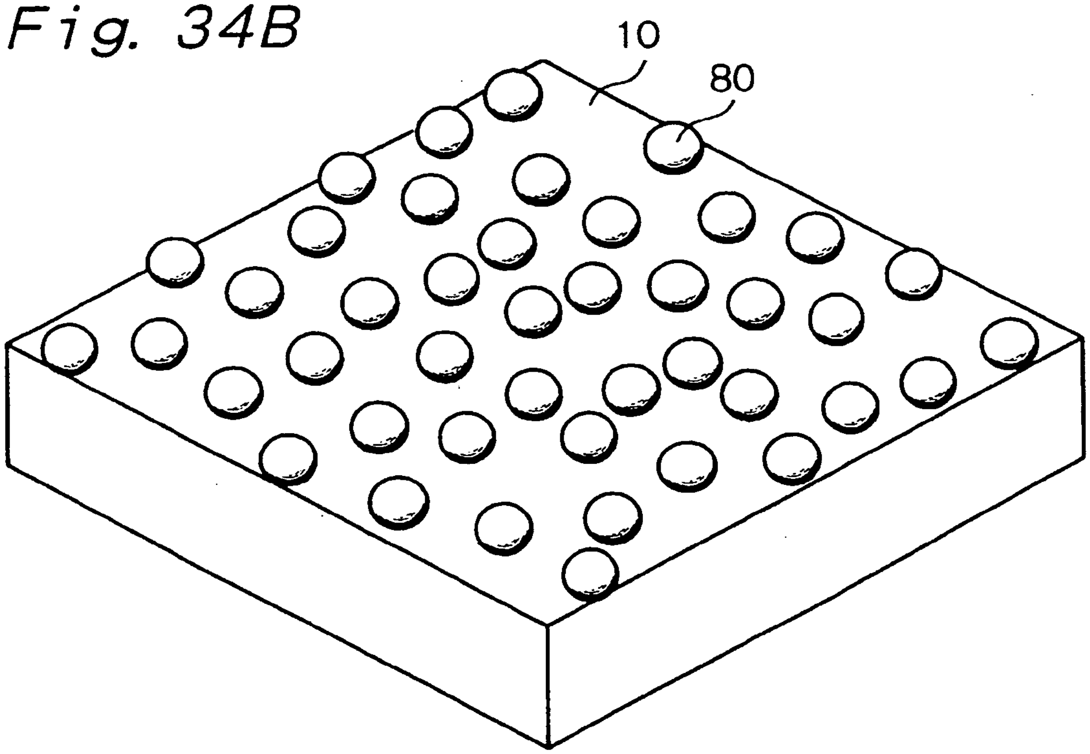


Fig. 35A

[STEP−1710]

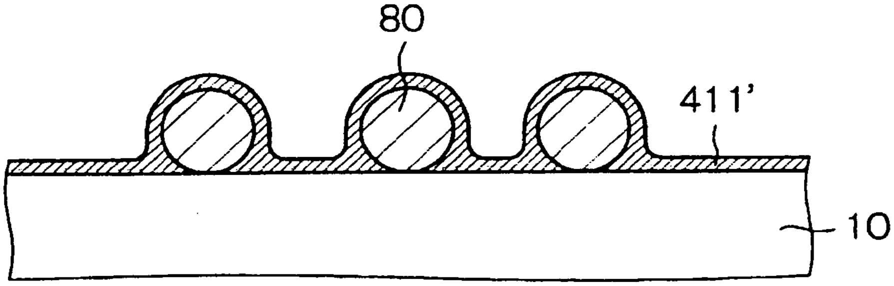


Fig. 35B

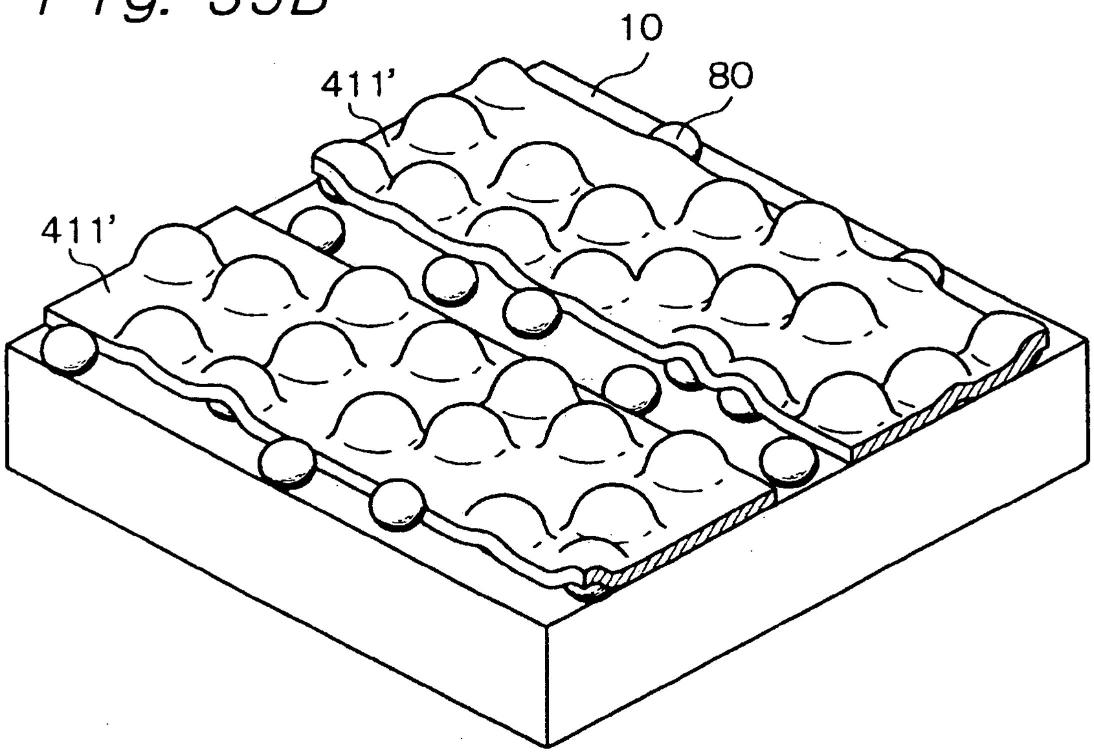


Fig. 36A

[STEP—1720]

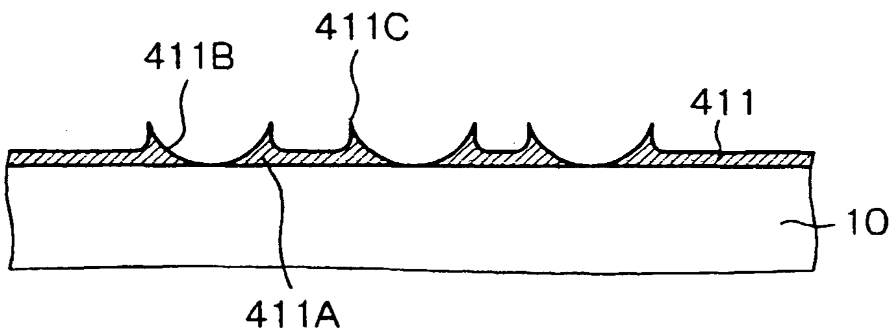


Fig. 36B

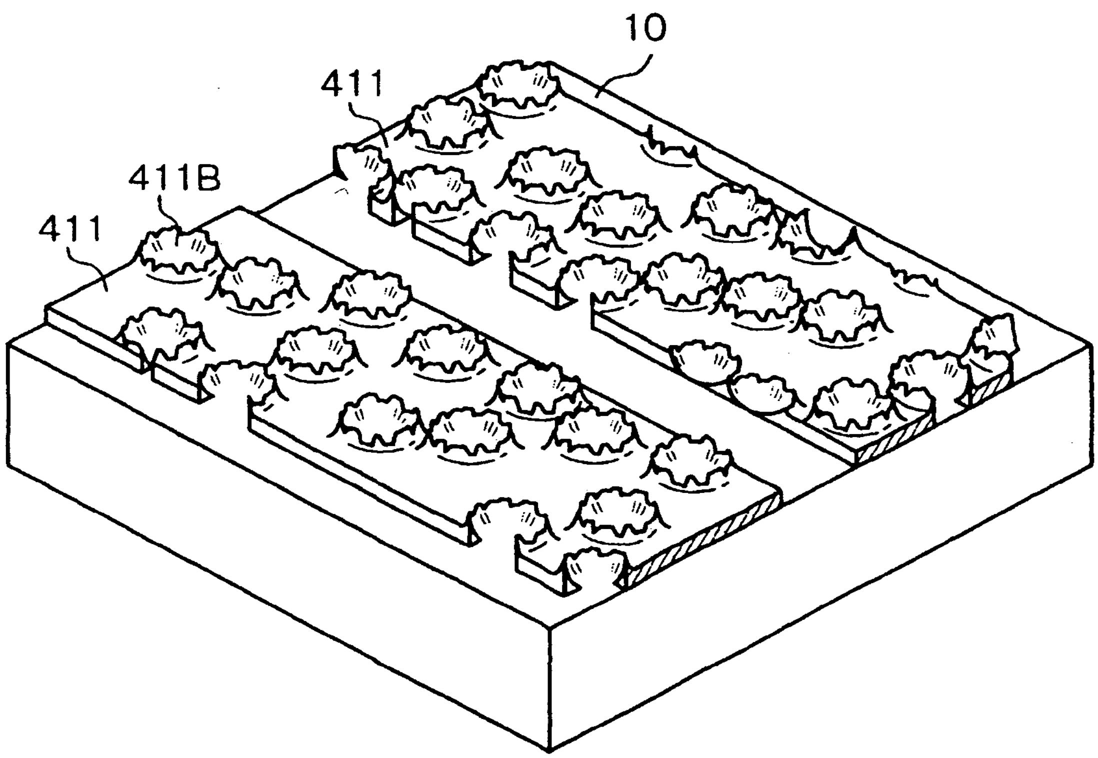


Fig. 37A

[STEP−1740]

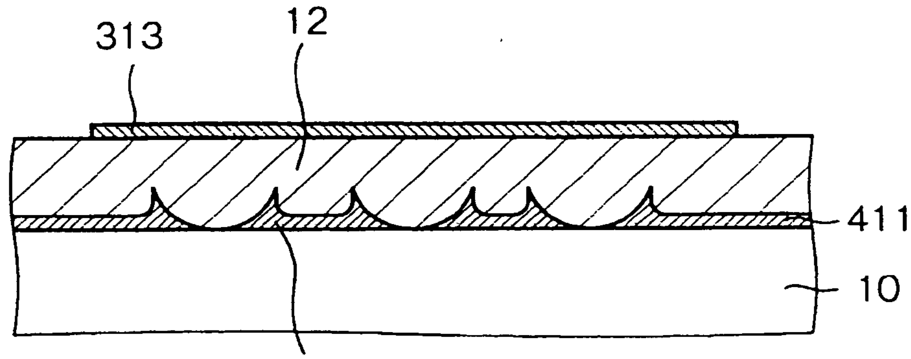


Fig. 37B

[STEP−1750]

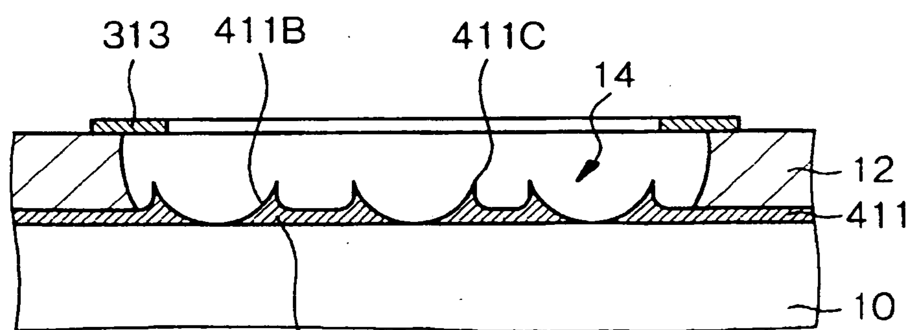


Fig. 38A

[STEP—1800]

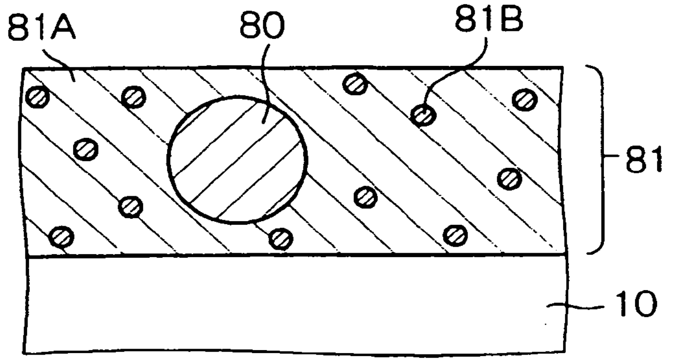


Fig. 38B

[STEP—1810]

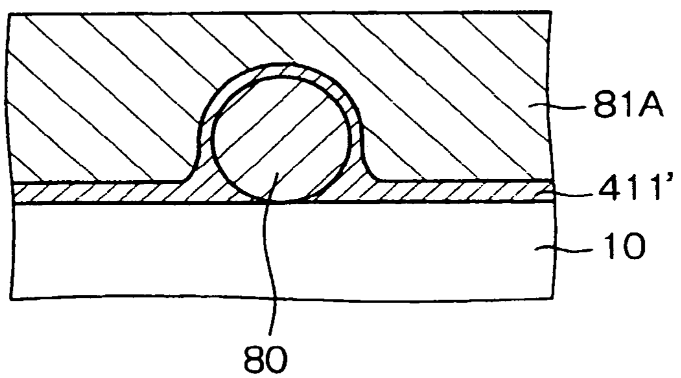


Fig. 38C

[STEP—1820]

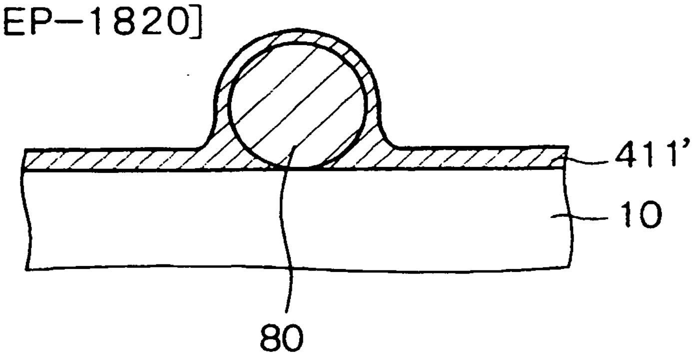


Fig. 39A

[STEP–1900]

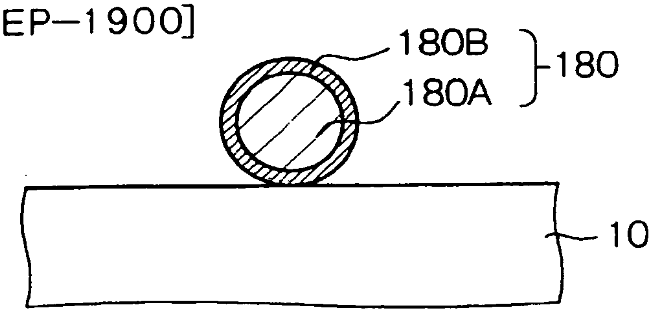


Fig. 39B

[STEP–1910]

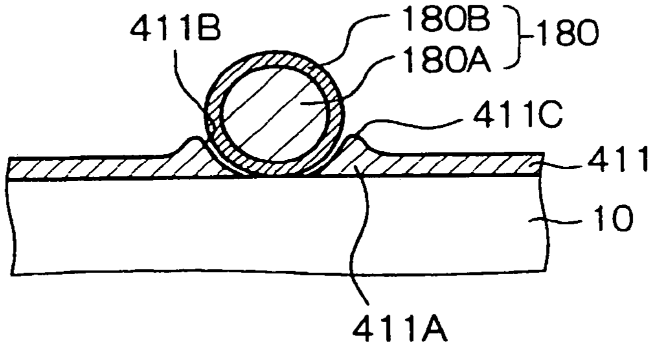


Fig. 39C

[STEP–1920]

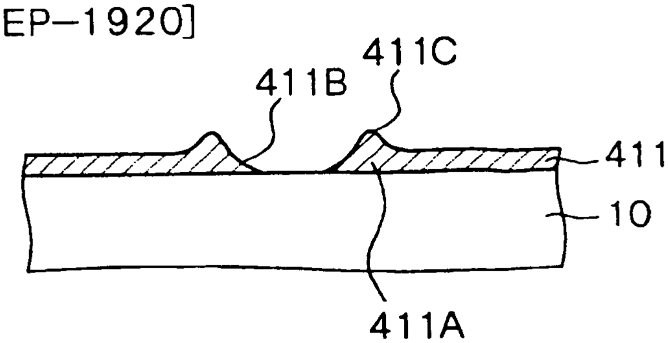


Fig. 40A

[STEP–2020]

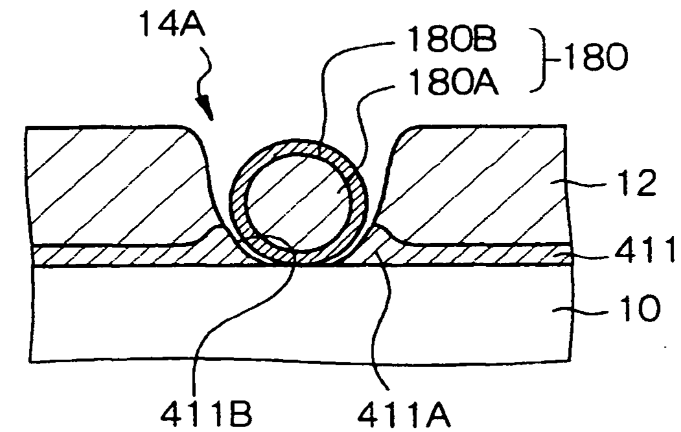


Fig. 40B

[STEP–2030]

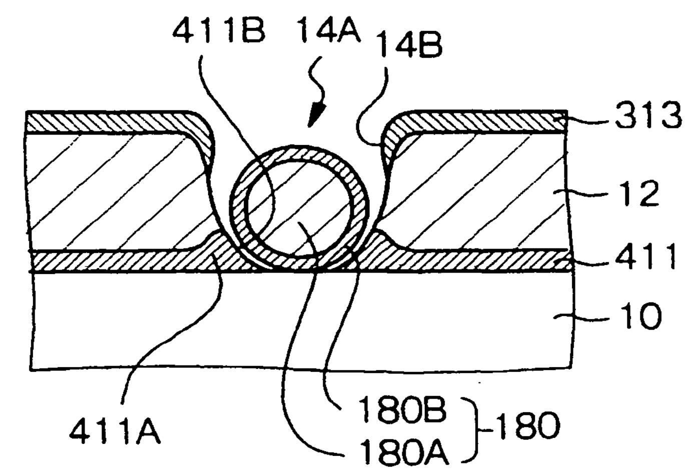


Fig. 41A

[STEP-2040]

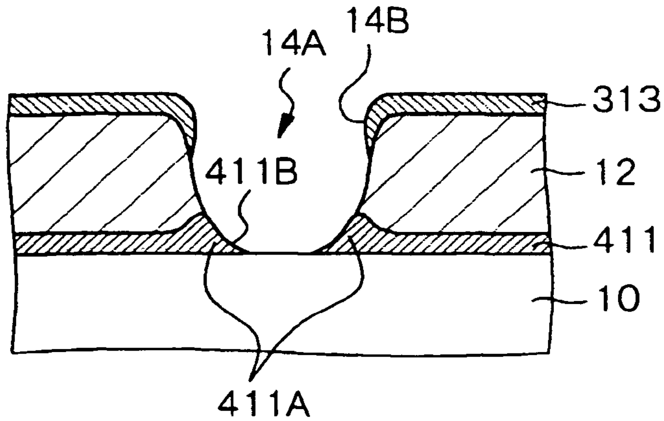


Fig. 41B

[STEP-2050]

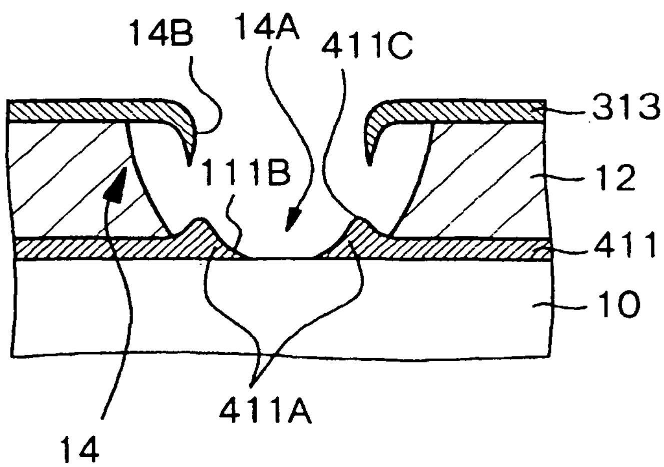


Fig. 42A

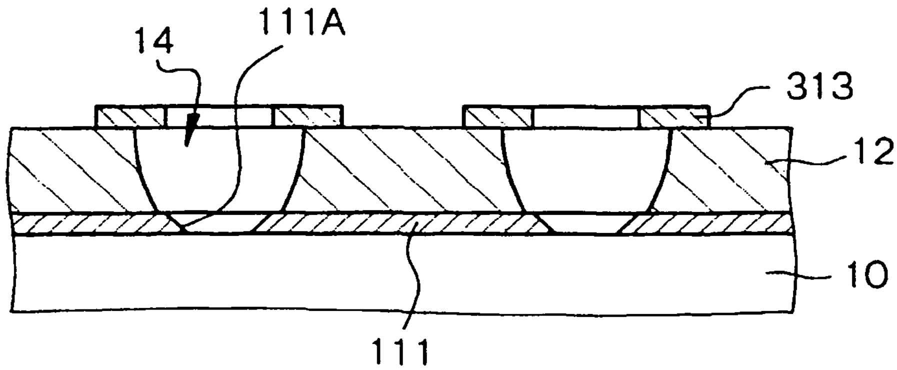


Fig. 42B

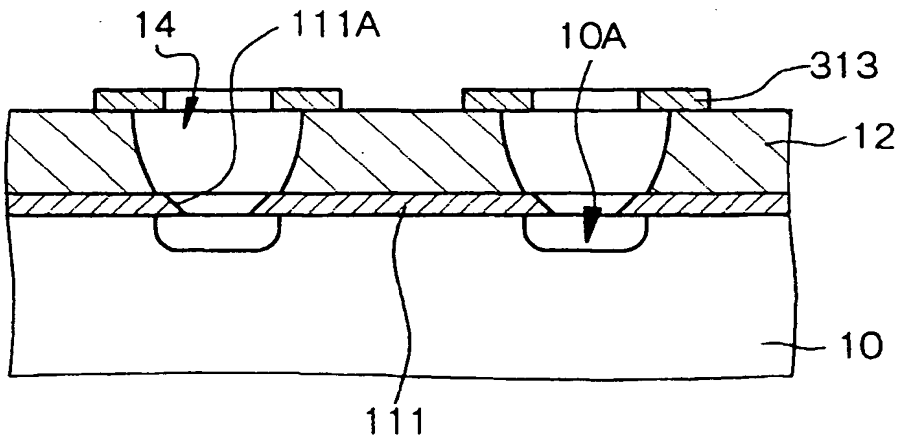


Fig. 42C

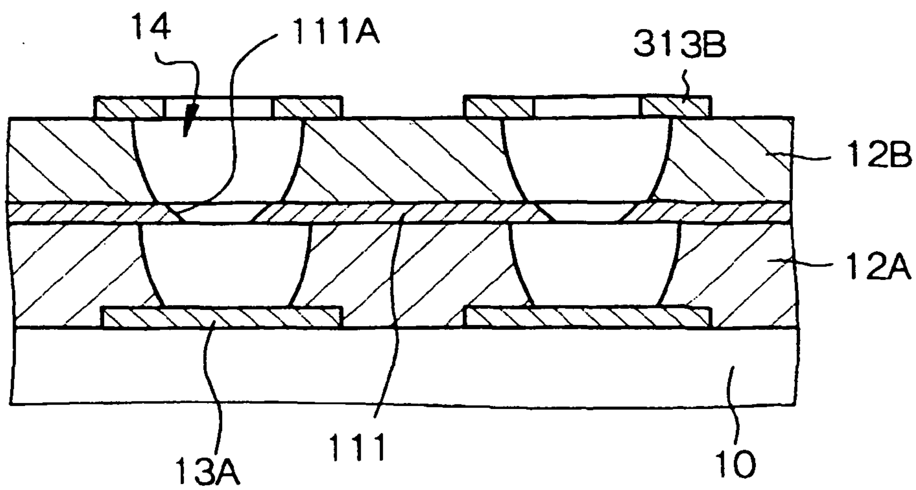


Fig. 43A

[STEP-2100]

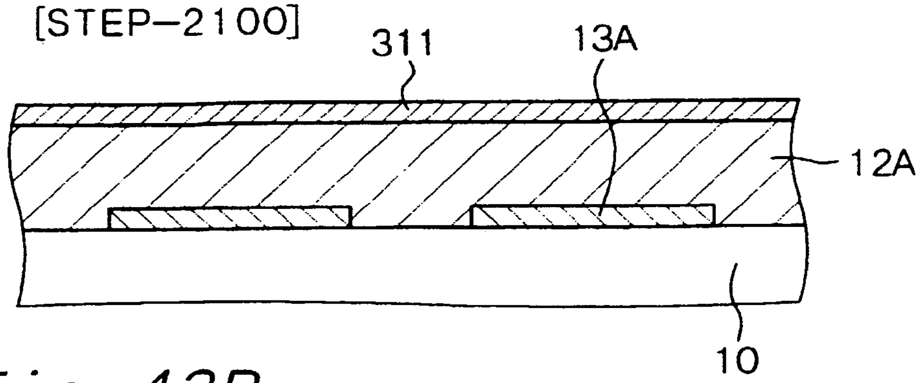


Fig. 43B

[STEP-2110]

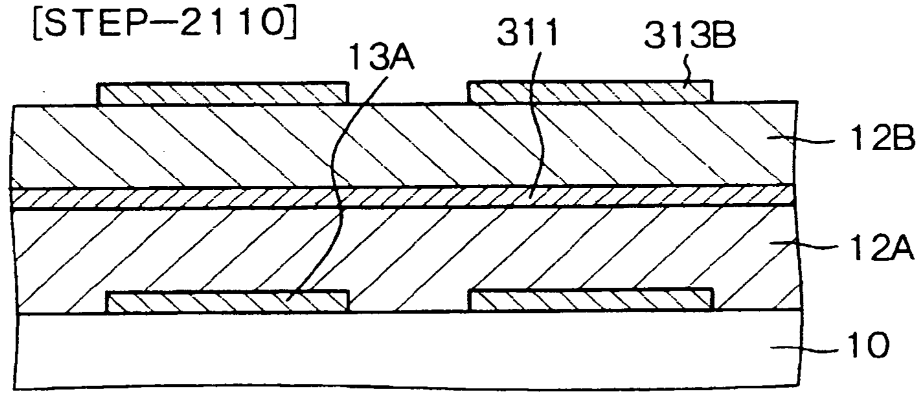


Fig. 43C

[STEP-2120]

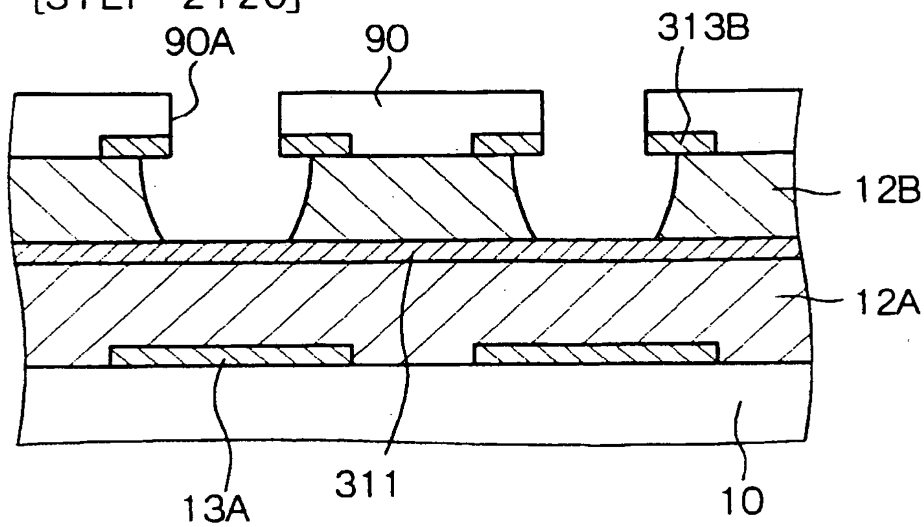


Fig. 44A

[STEP—2200]

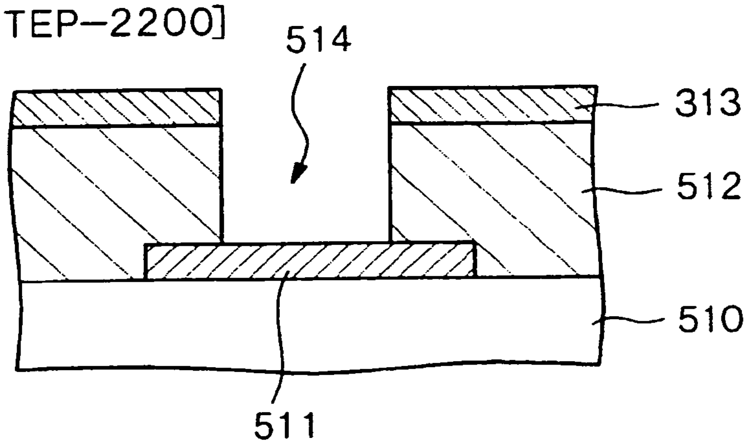


Fig. 44B

[STEP—2210]

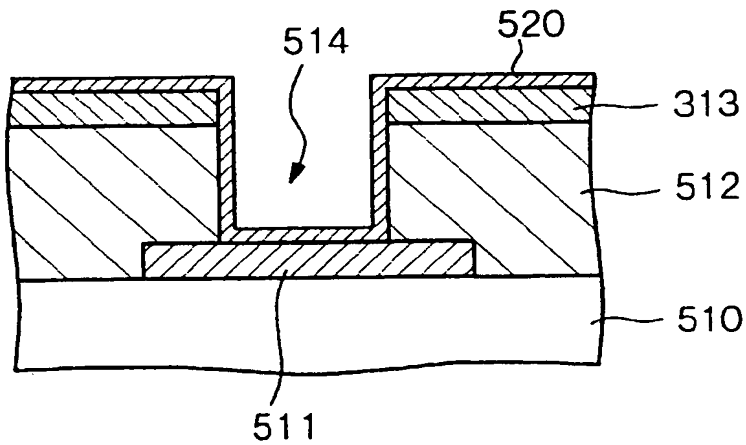


Fig. 45A

[STEP–2220]

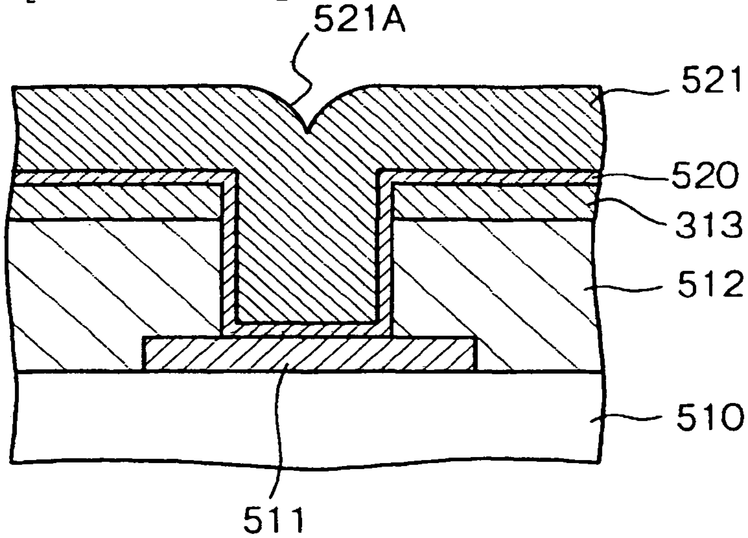


Fig. 45B

[STEP–2230]

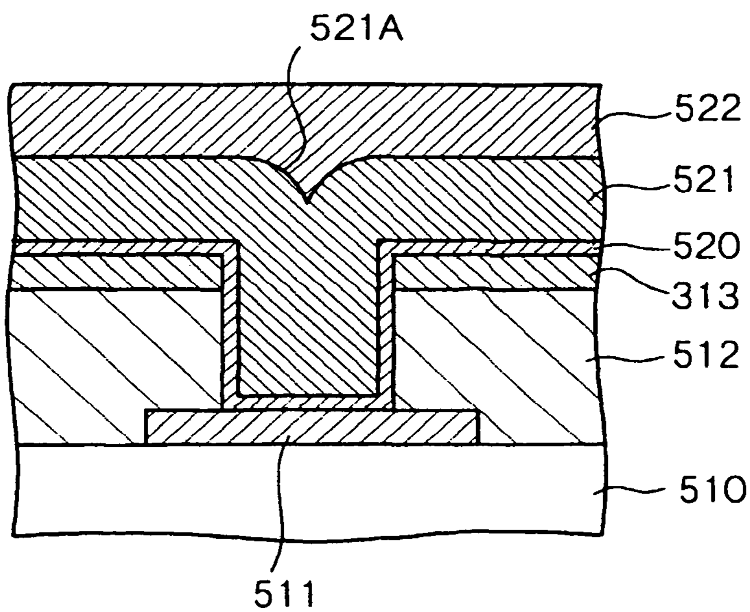


Fig. 46A

[STEP-2230] CONTINUED

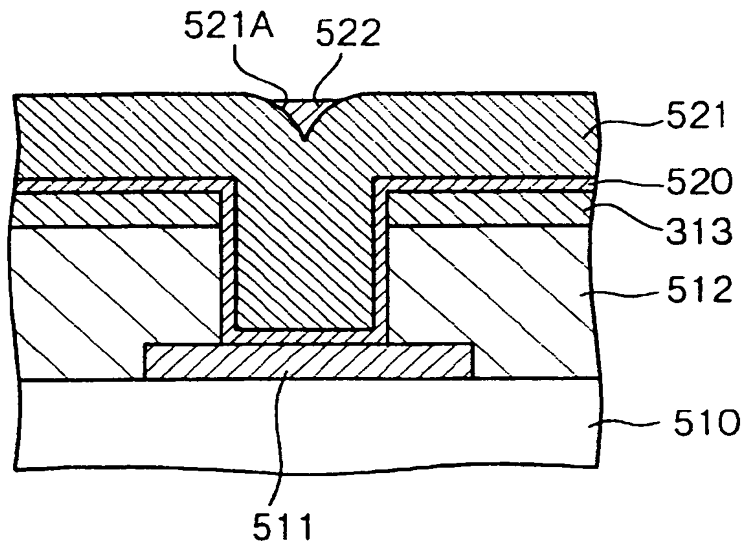


Fig. 46B

[STEP-2240]

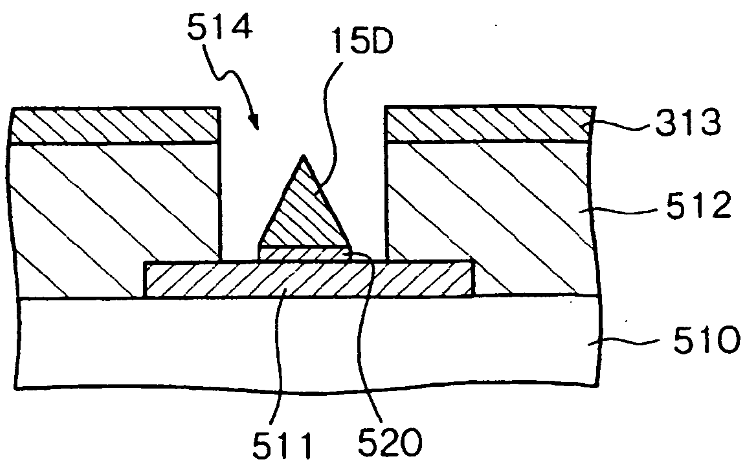


Fig. 47

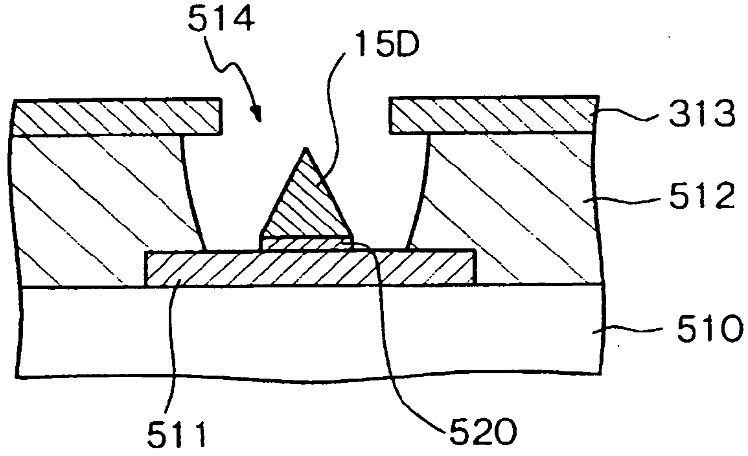


Fig. 48A

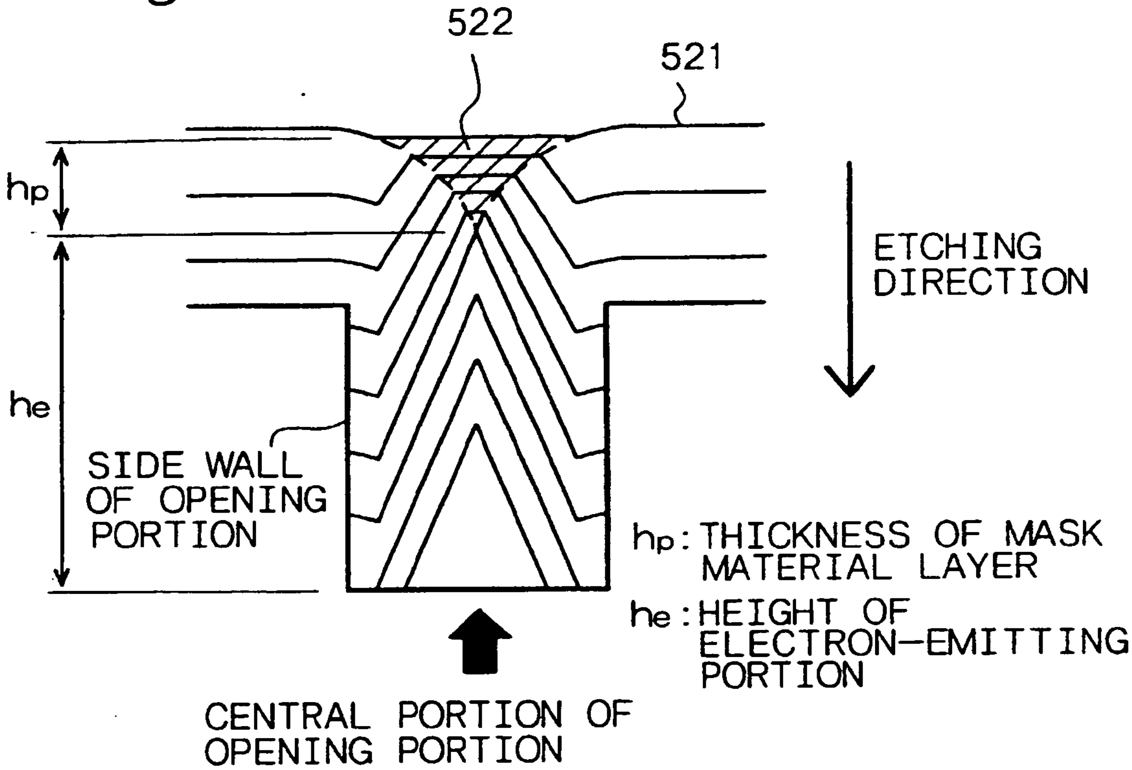


Fig. 48B

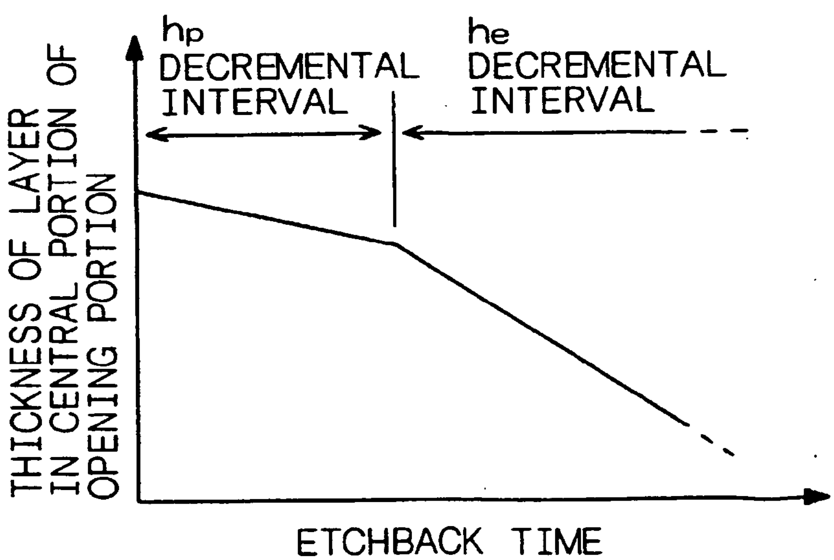


Fig. 49A

SELECTION RATIO TO RESIST
: SMALL

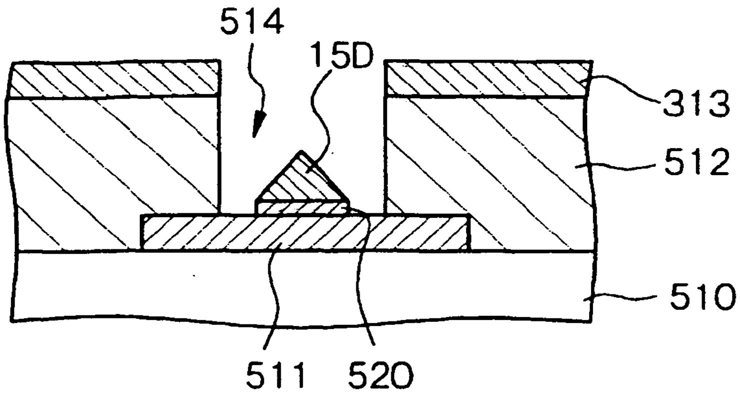


Fig. 49B

SELECTION RATIO TO RESIST
: INTERMEDIATE

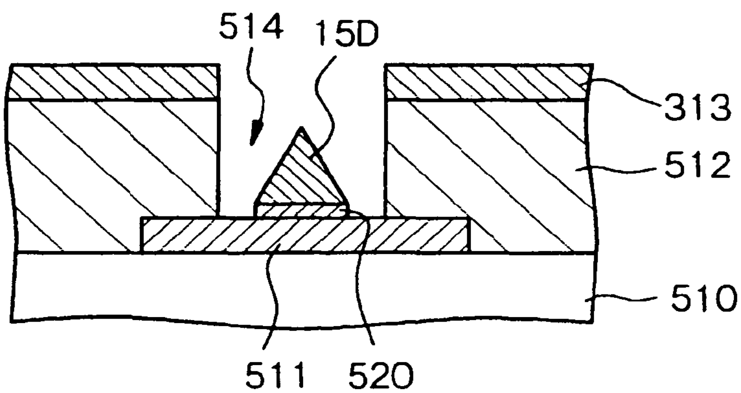


Fig. 49C

SELECTION RATIO TO RESIST
: LARGE

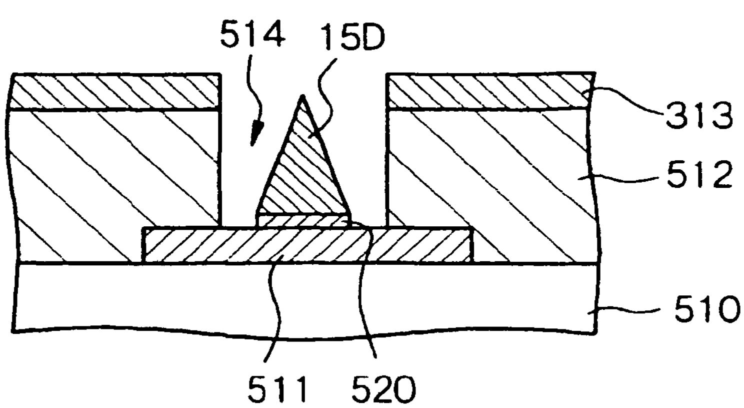


Fig. 50A

[STEP-2300]

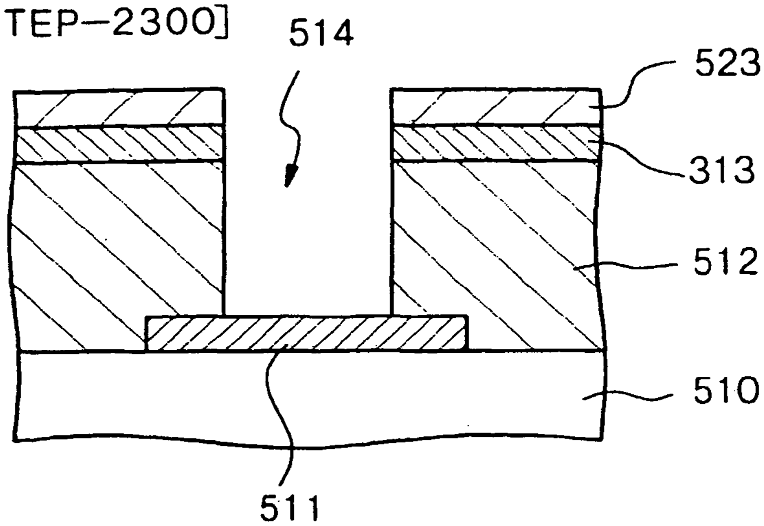


Fig. 50B

[STEP-2310]

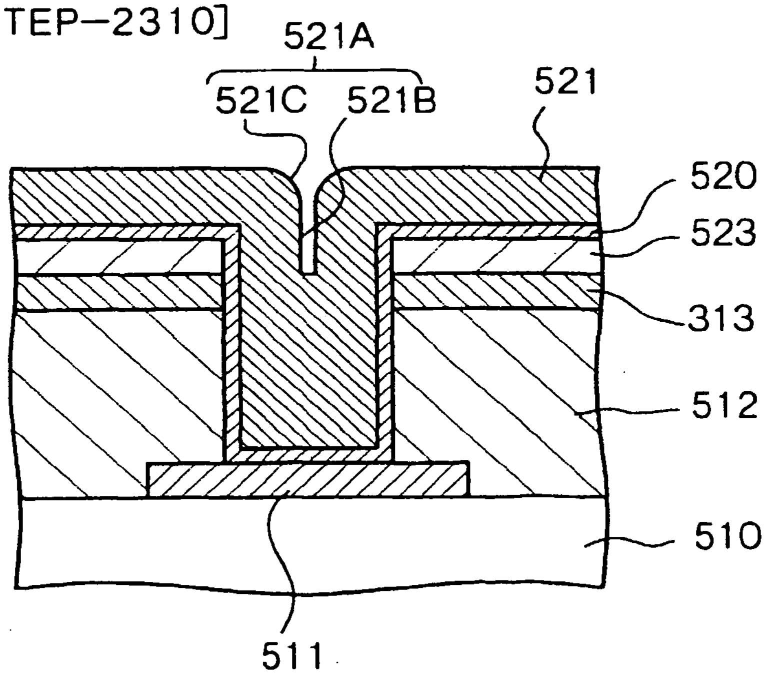


Fig. 51A

[STEP-2320]

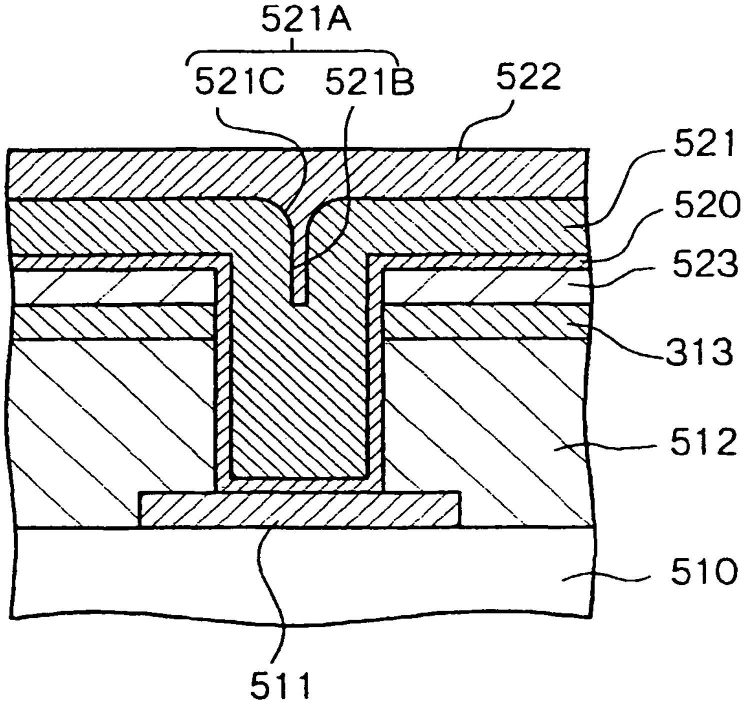


Fig. 51B

[STEP-2330]

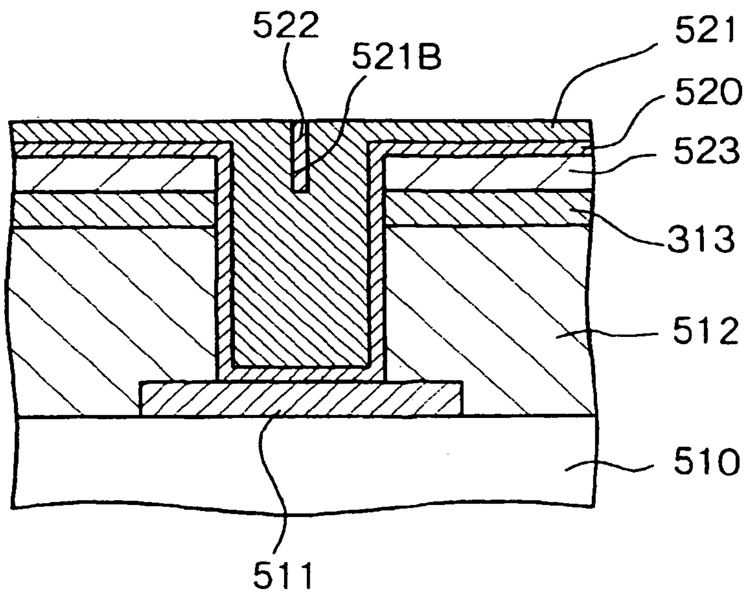


Fig. 52A

[STEP−2340]

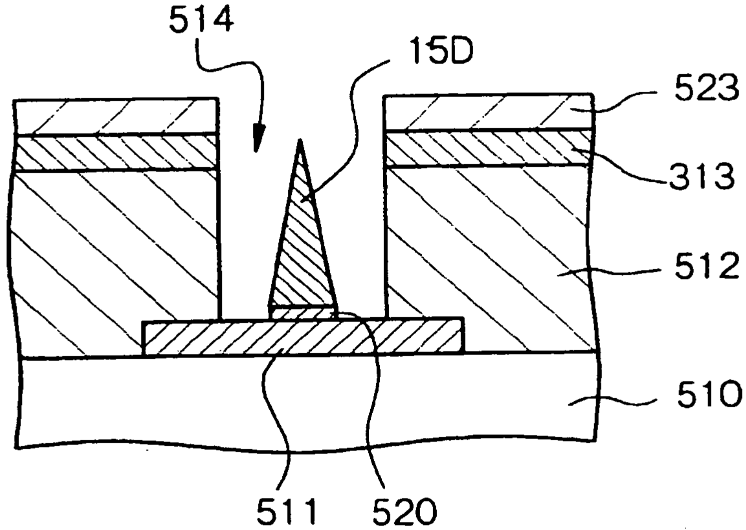


Fig. 52B

[STEP−2350]

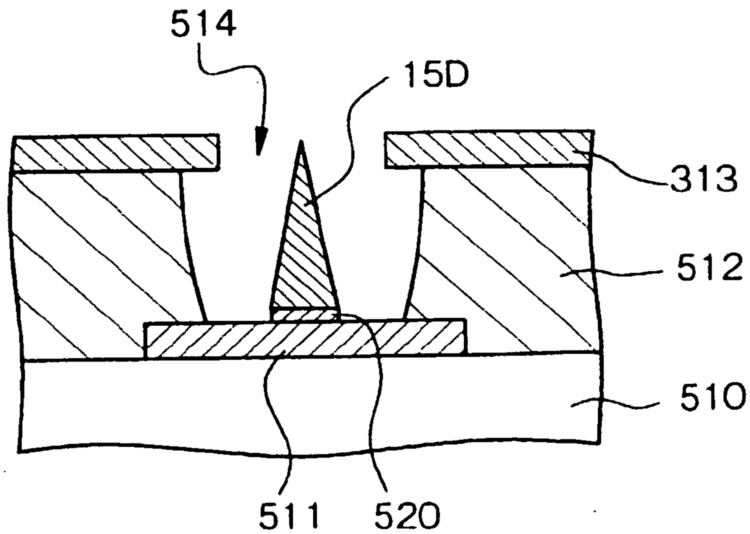


Fig. 53A

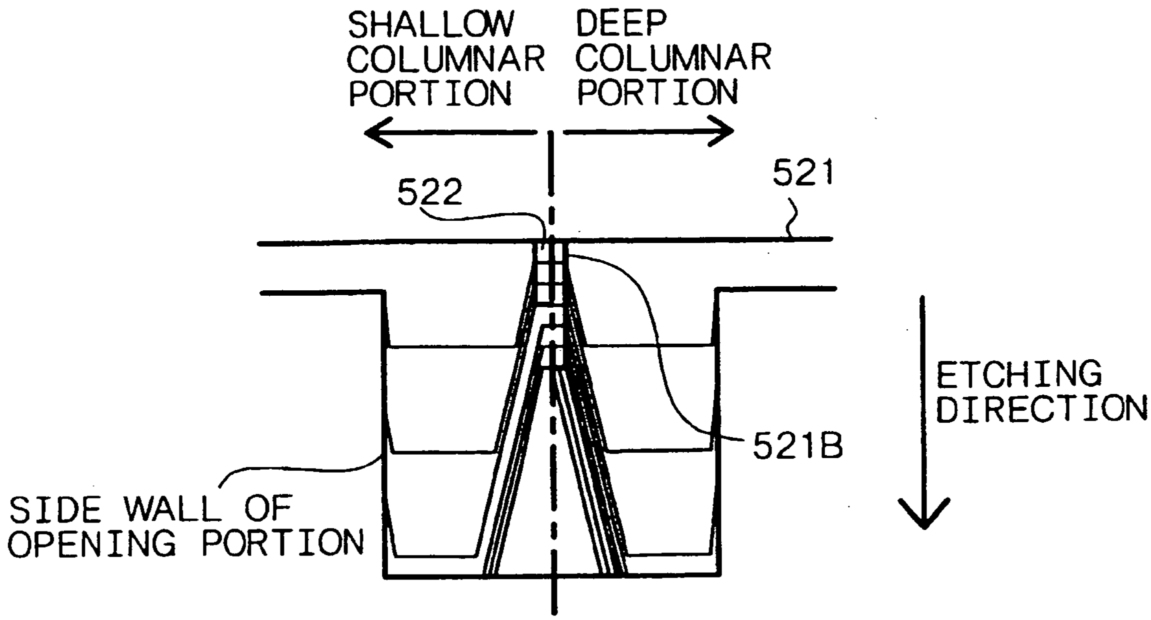


Fig. 53B

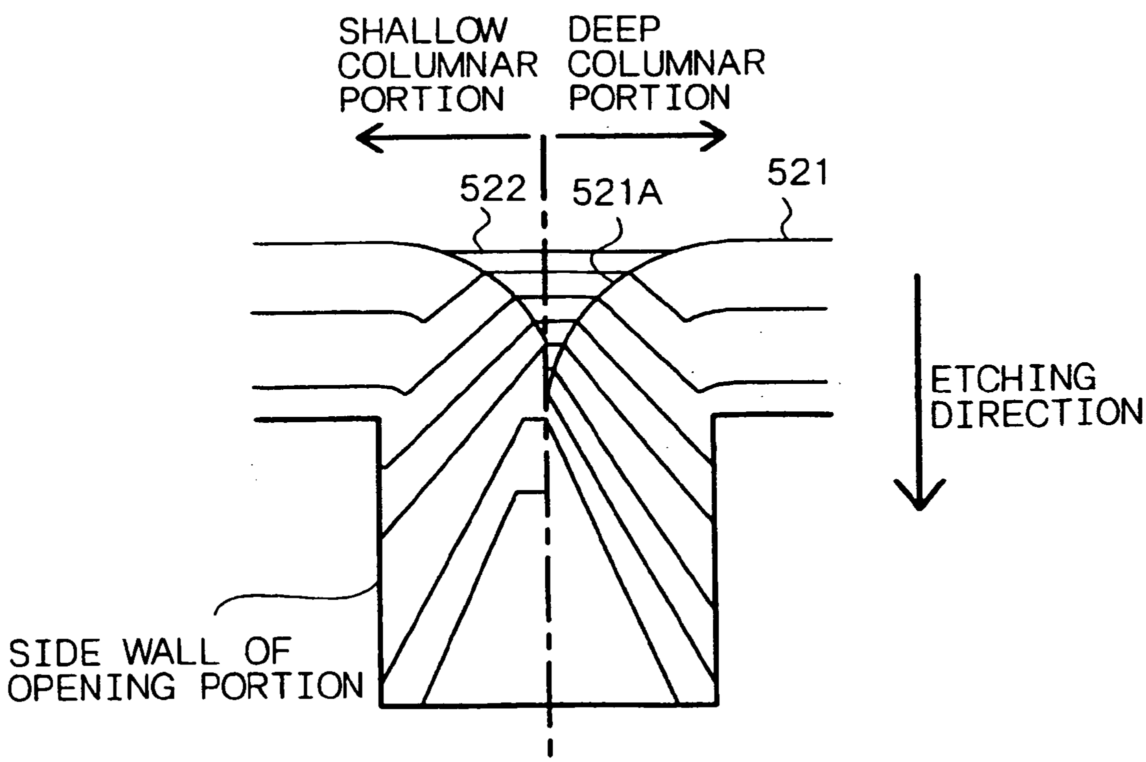


Fig. 54A

[STEP-2400]

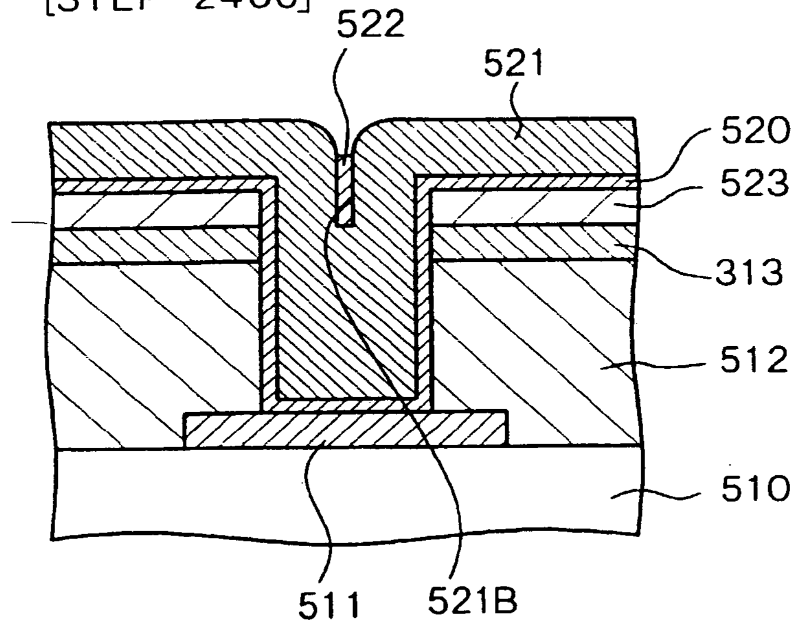


Fig. 54B

[STEP-2410]

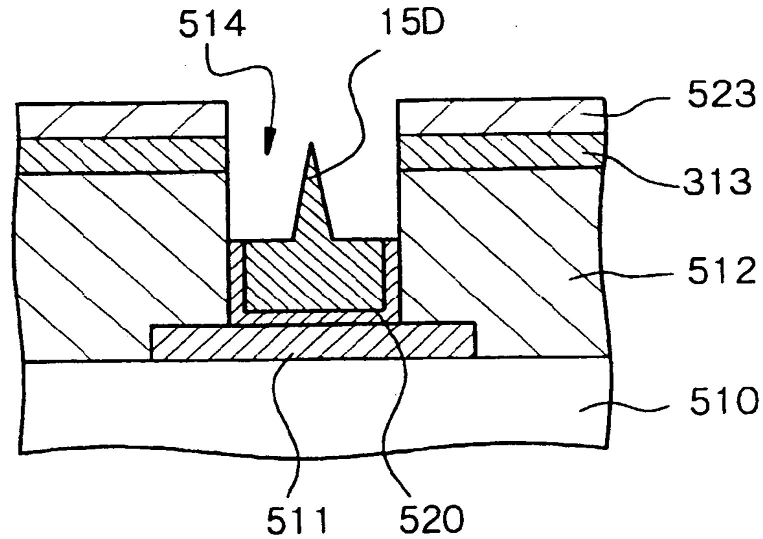


Fig. 55

[STEP-2420]

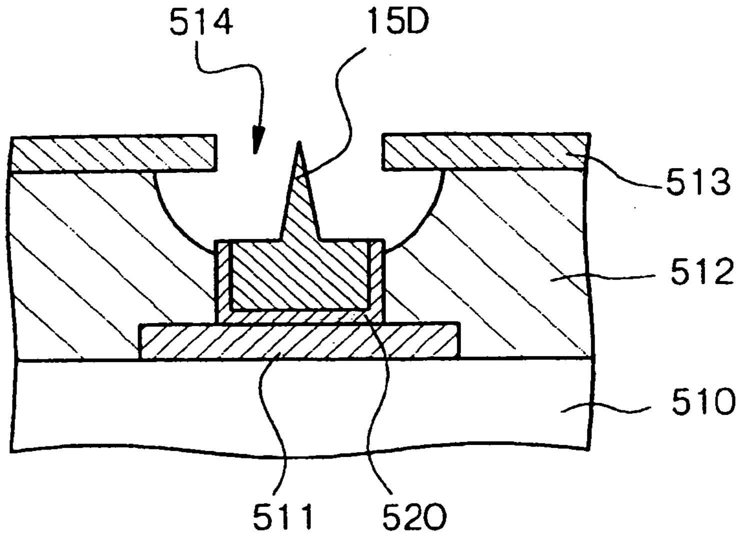


Fig. 56

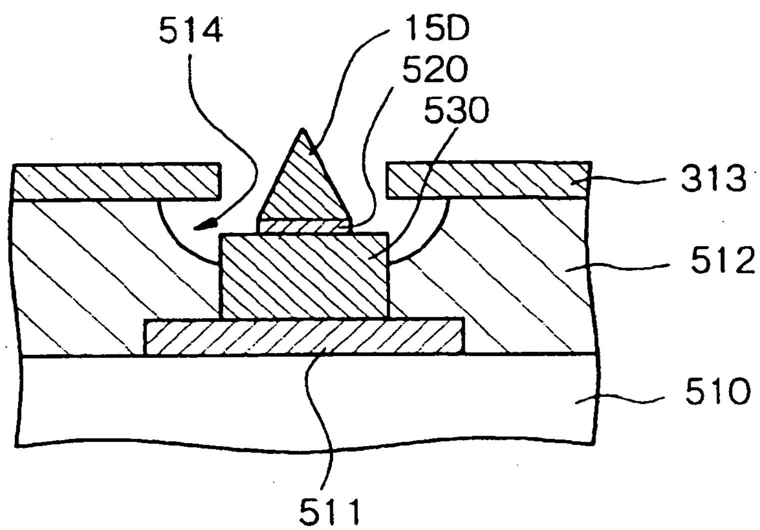


Fig. 57A

[STEP–2500]

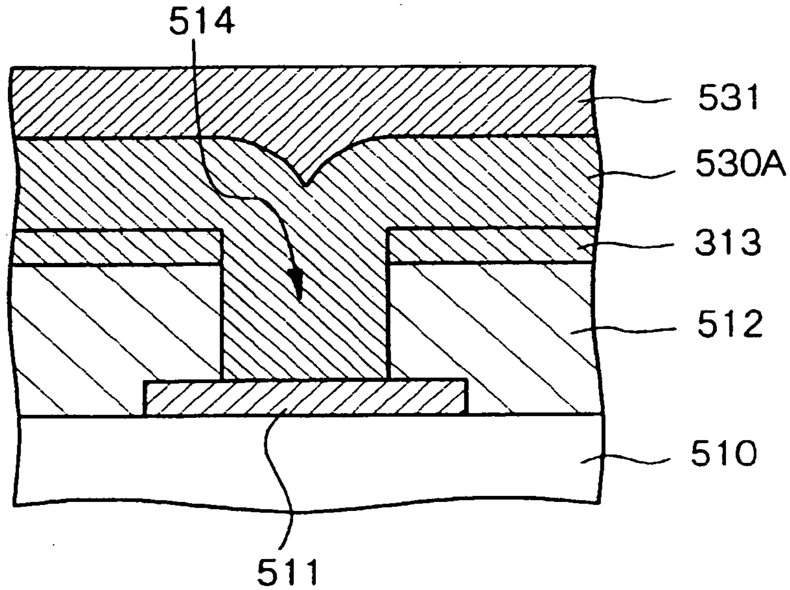


Fig. 57B

[STEP–2500] CONTINUED

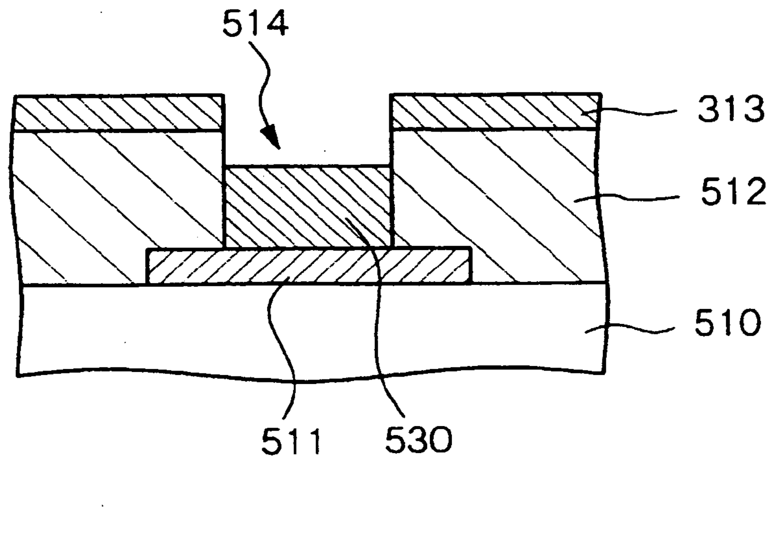


Fig. 58A

[STEP-2510]

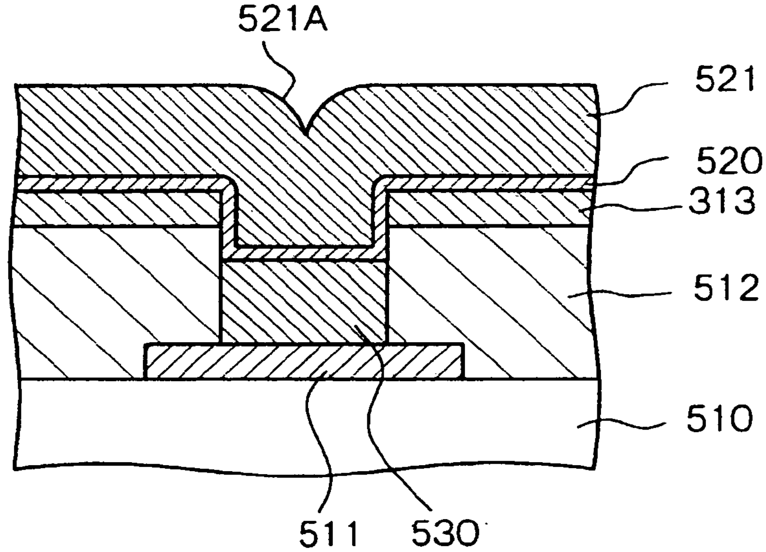


Fig. 58B

[STEP-2520]

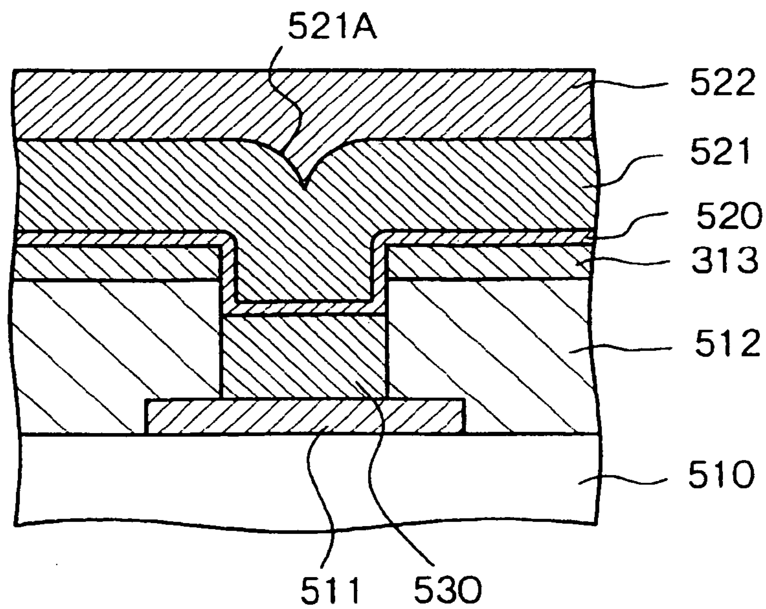


Fig. 59A

[STEP–2520] CONTINUED

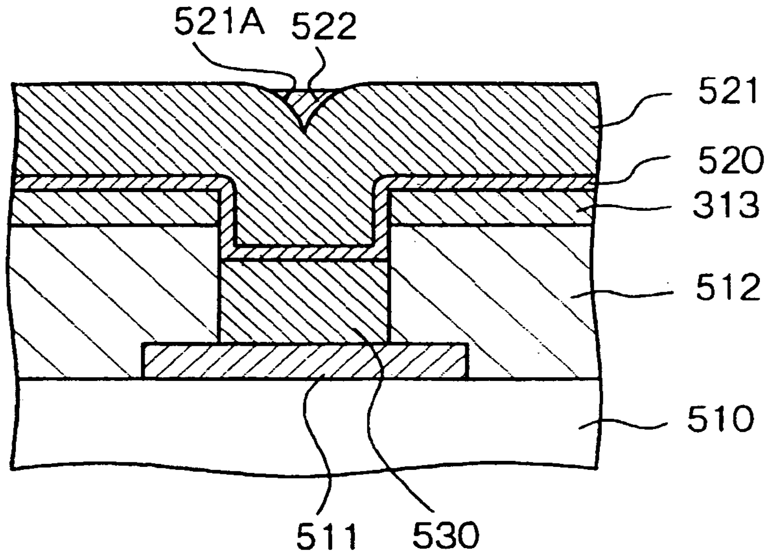


Fig. 59B

[STEP–2530]

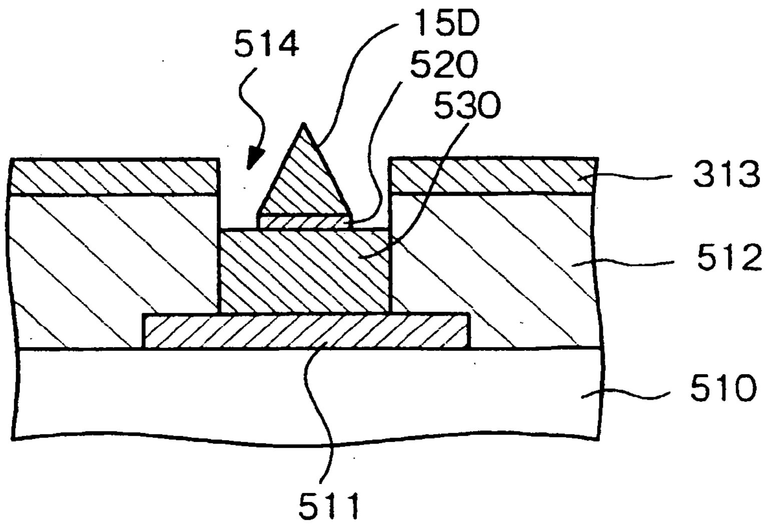


Fig. 60A

[STEP-2600]

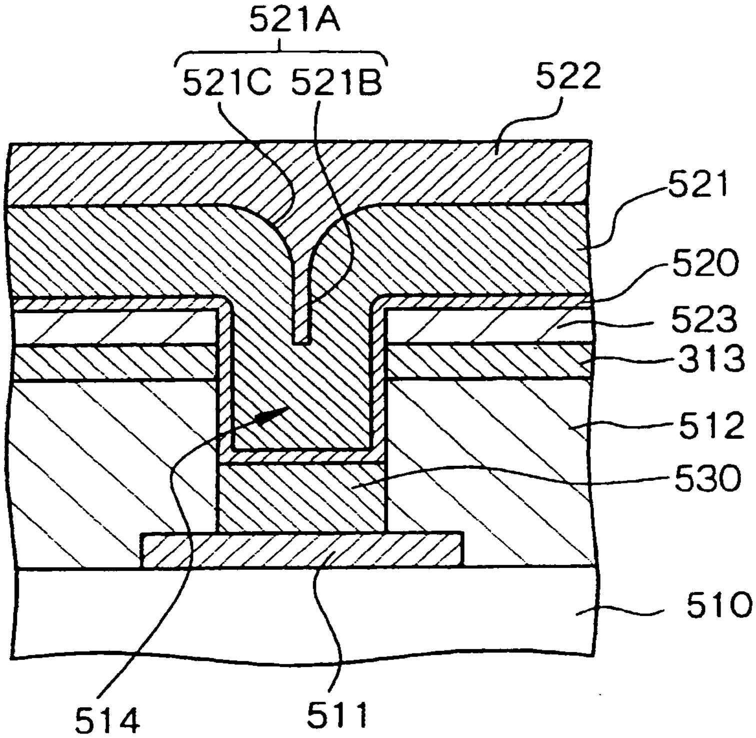


Fig. 60B

[STEP-2610]

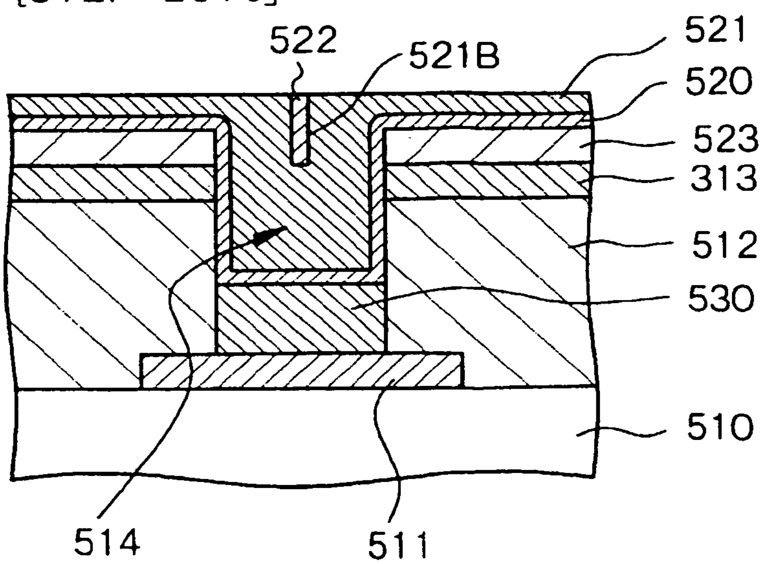


Fig. 61A

[STEP—2620]

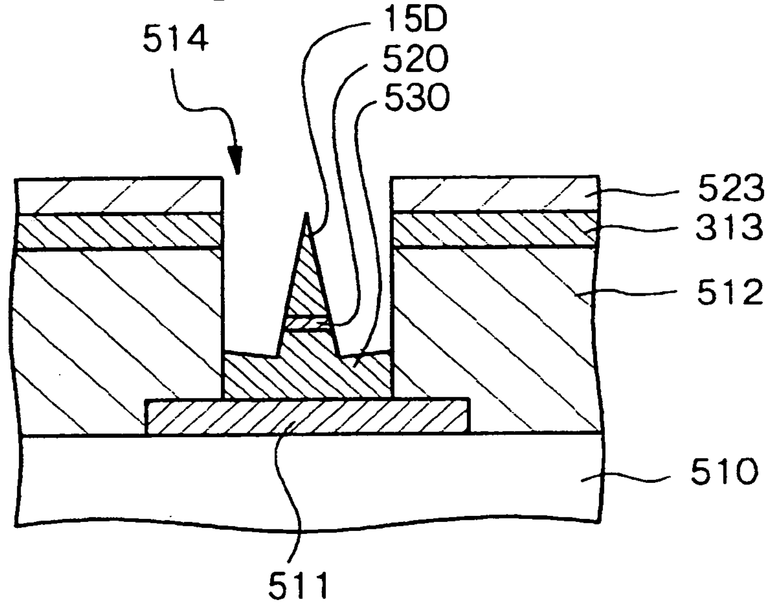


Fig. 61B

[STEP—2630]

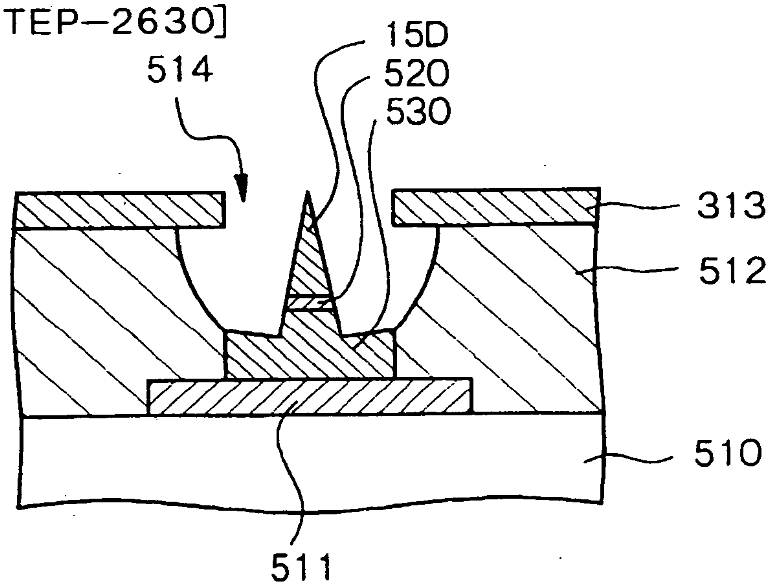
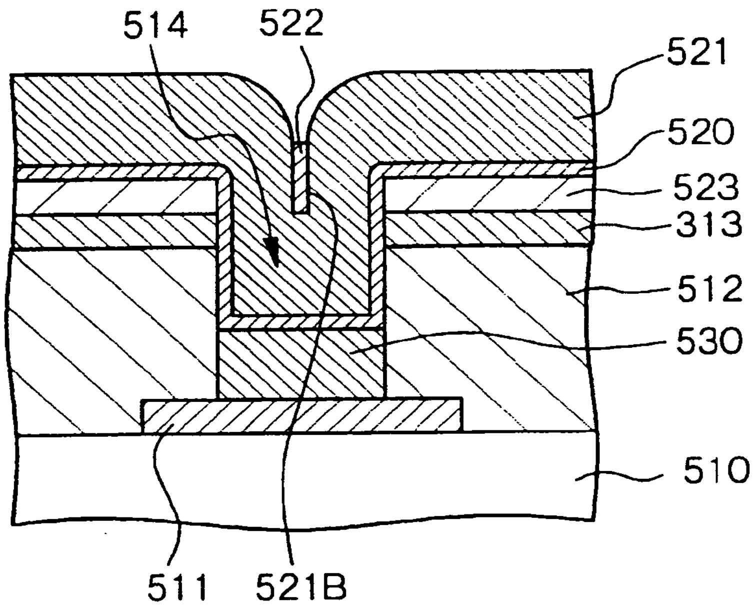


Fig. 62

[STEP–2700]



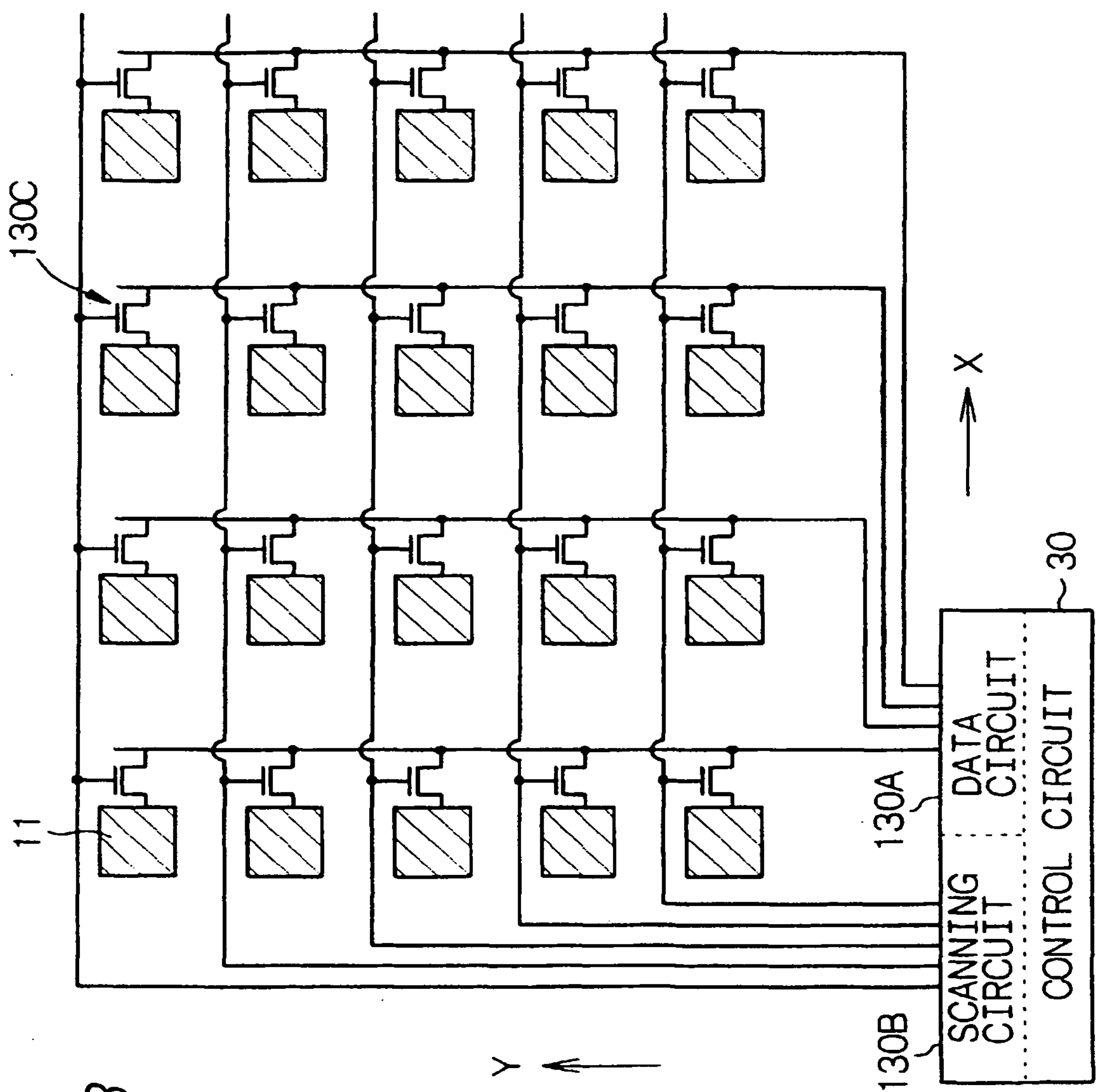

130C
11
X
Y
30
130A
130B
DATA CIRCUIT
SCANNING CIRCUIT
CONTROL CIRCUIT

Fig. 63

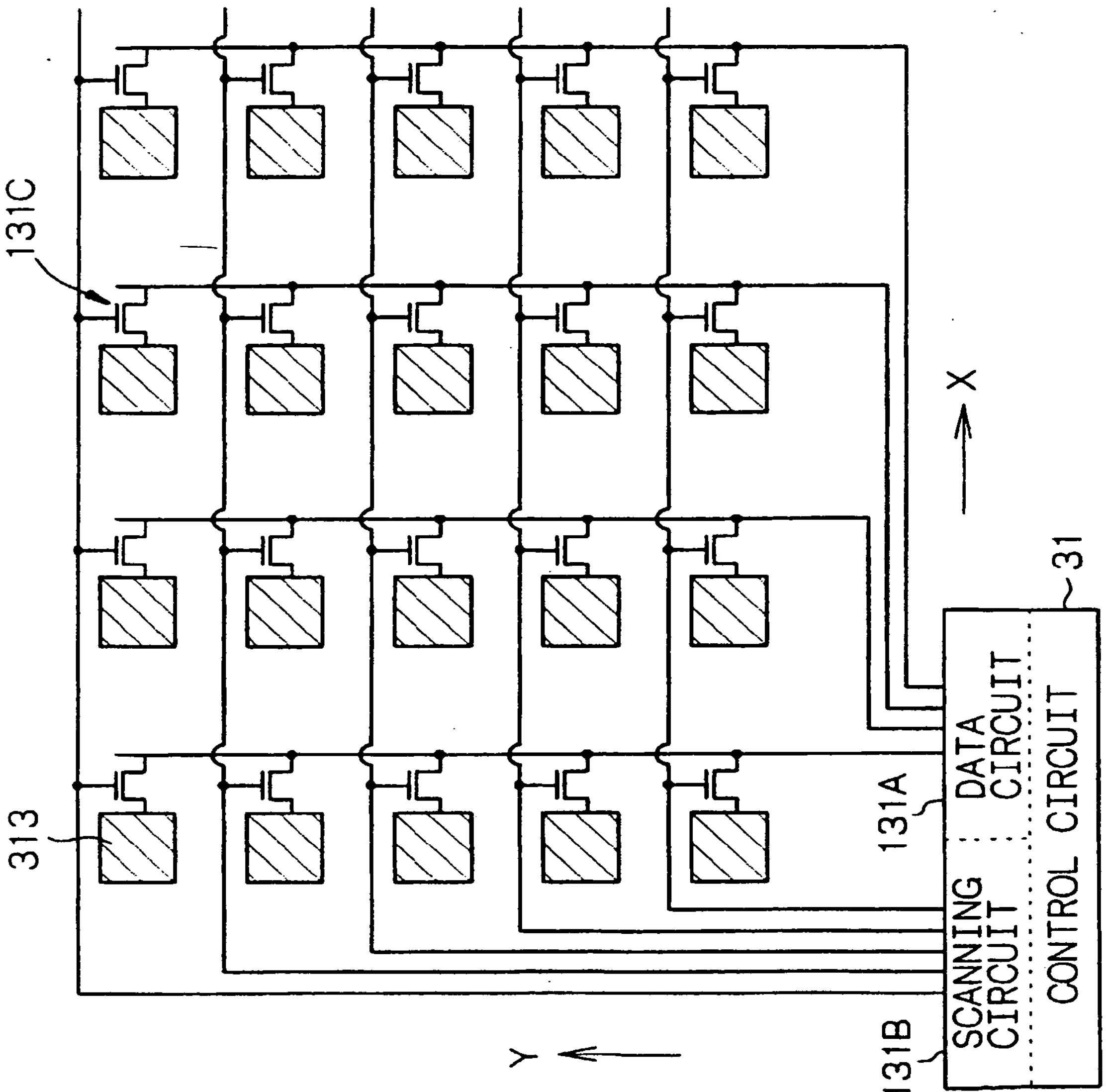

131C
313
X
Y
31
131A
131B
DATA CIRCUIT
SCANNING CIRCUIT
CONTROL CIRCUIT

Fig. 64

Fig. 65

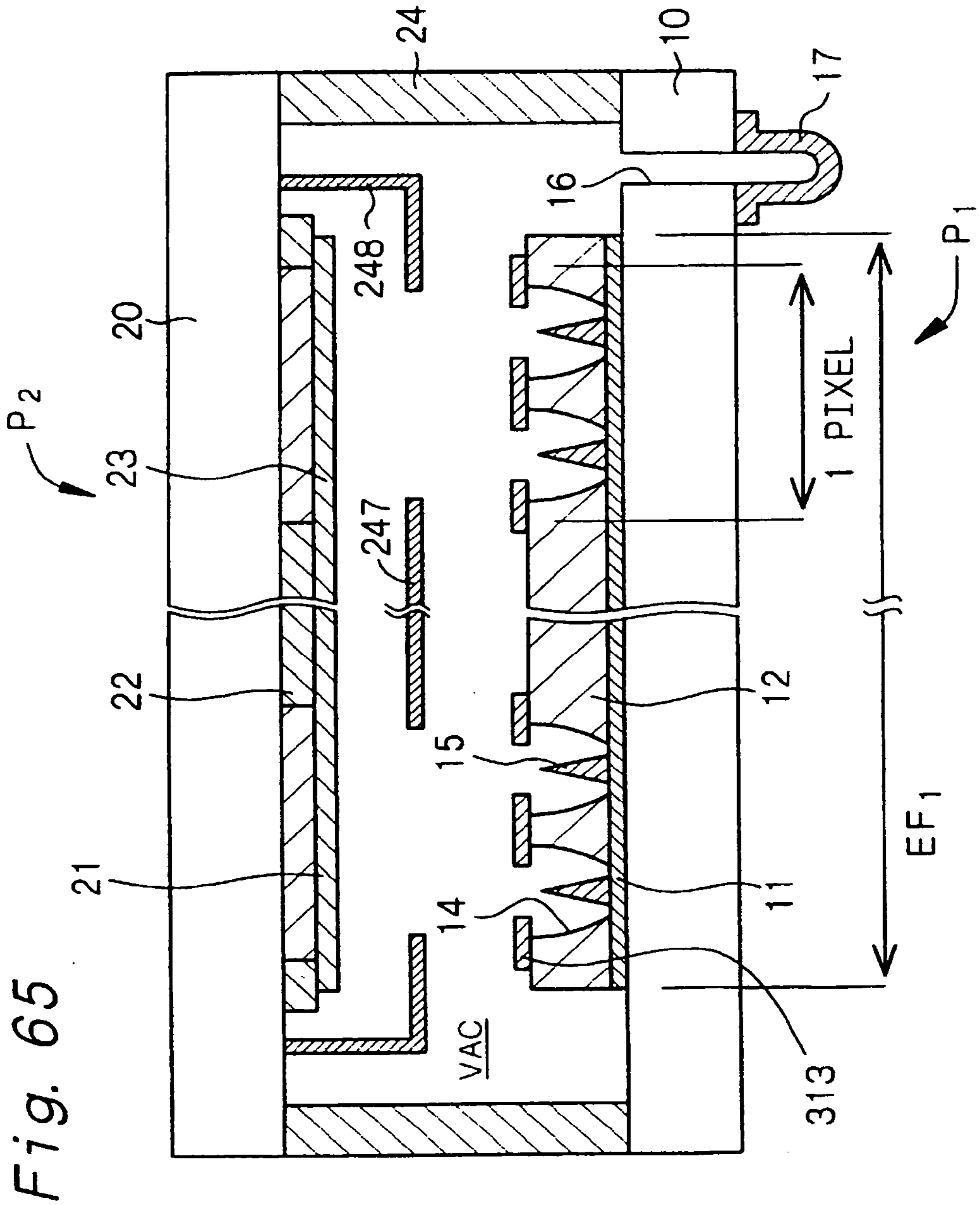


Fig. 66

(PRIOR ART)

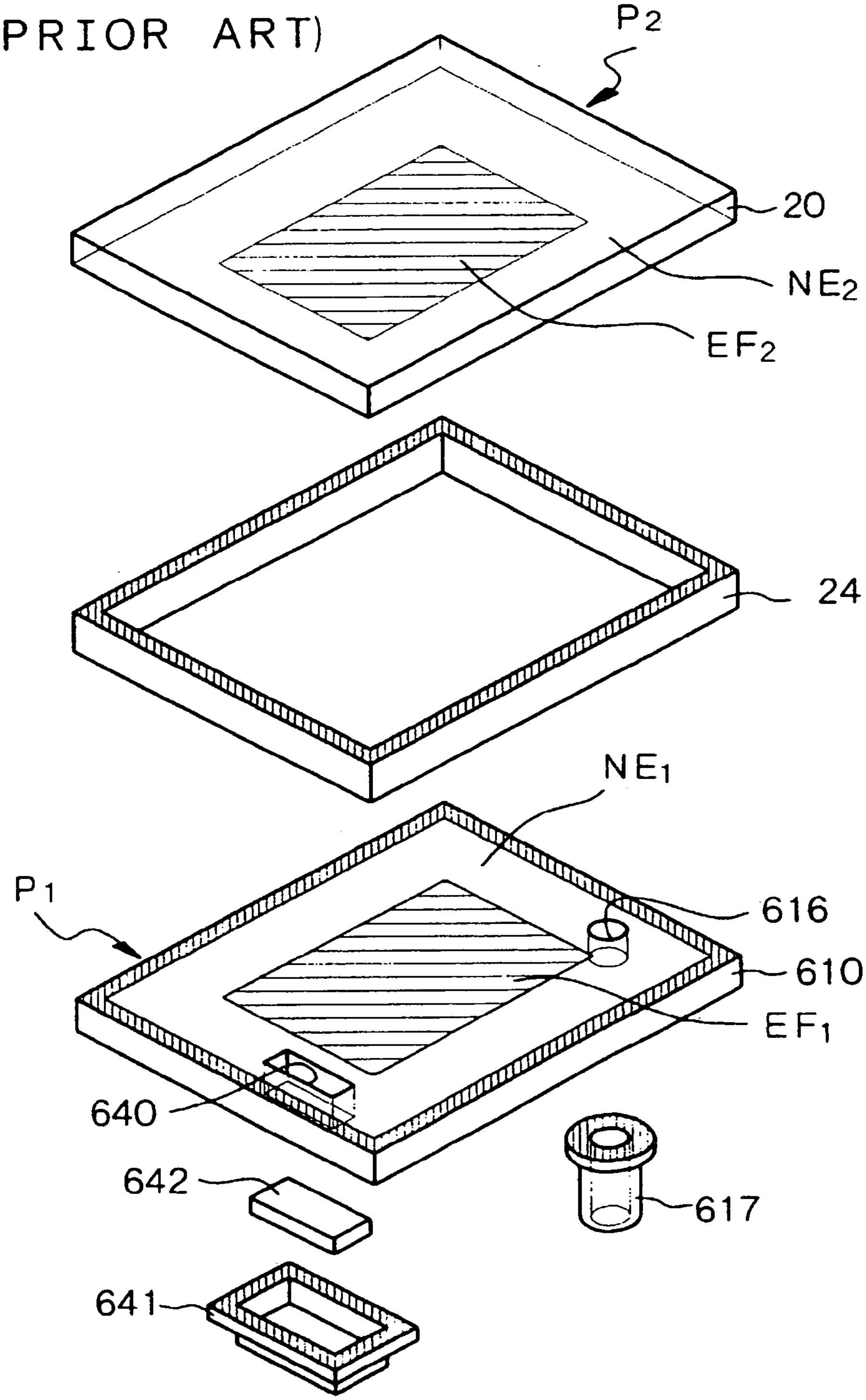


Fig. 67

(PRIOR ART)

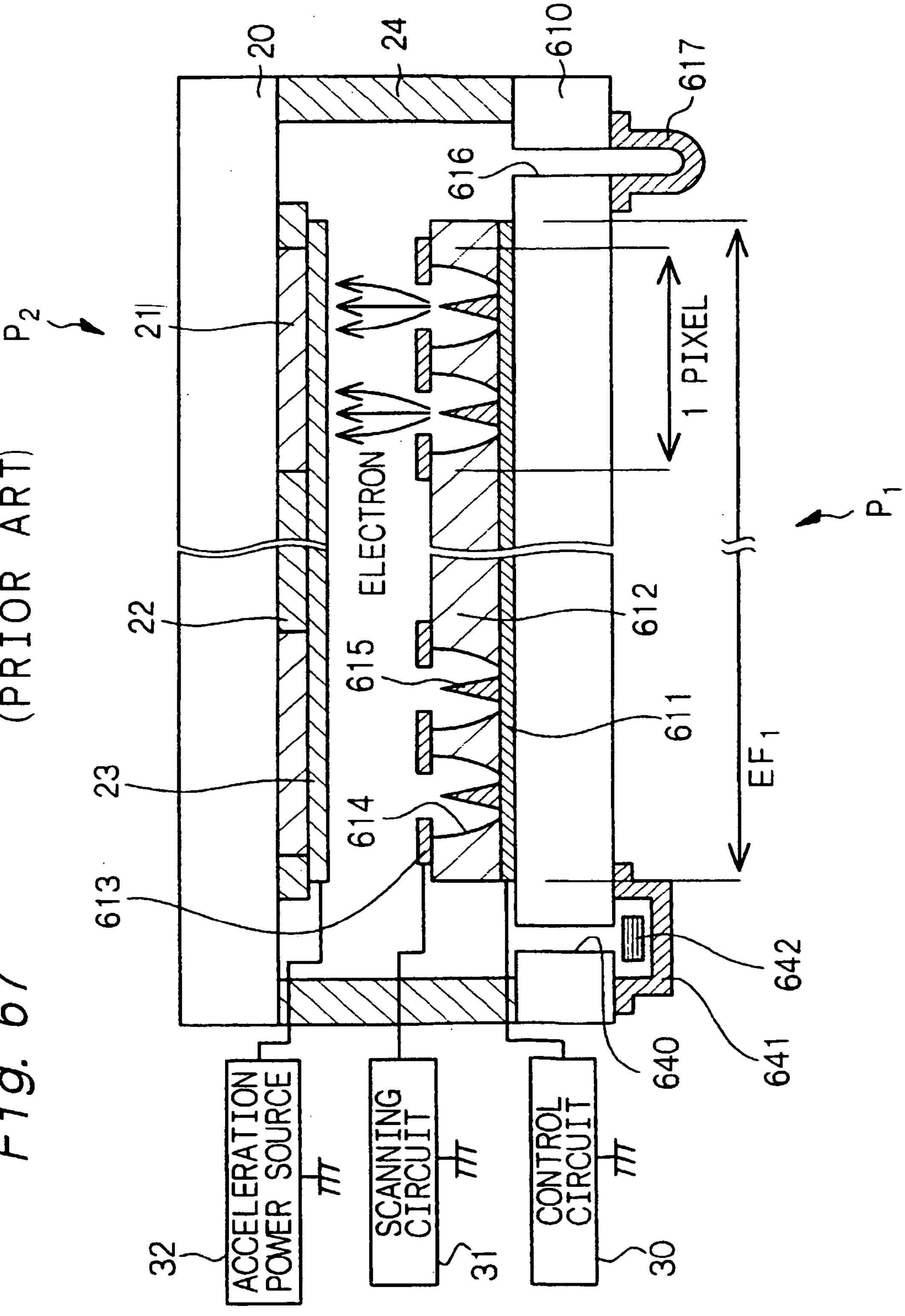
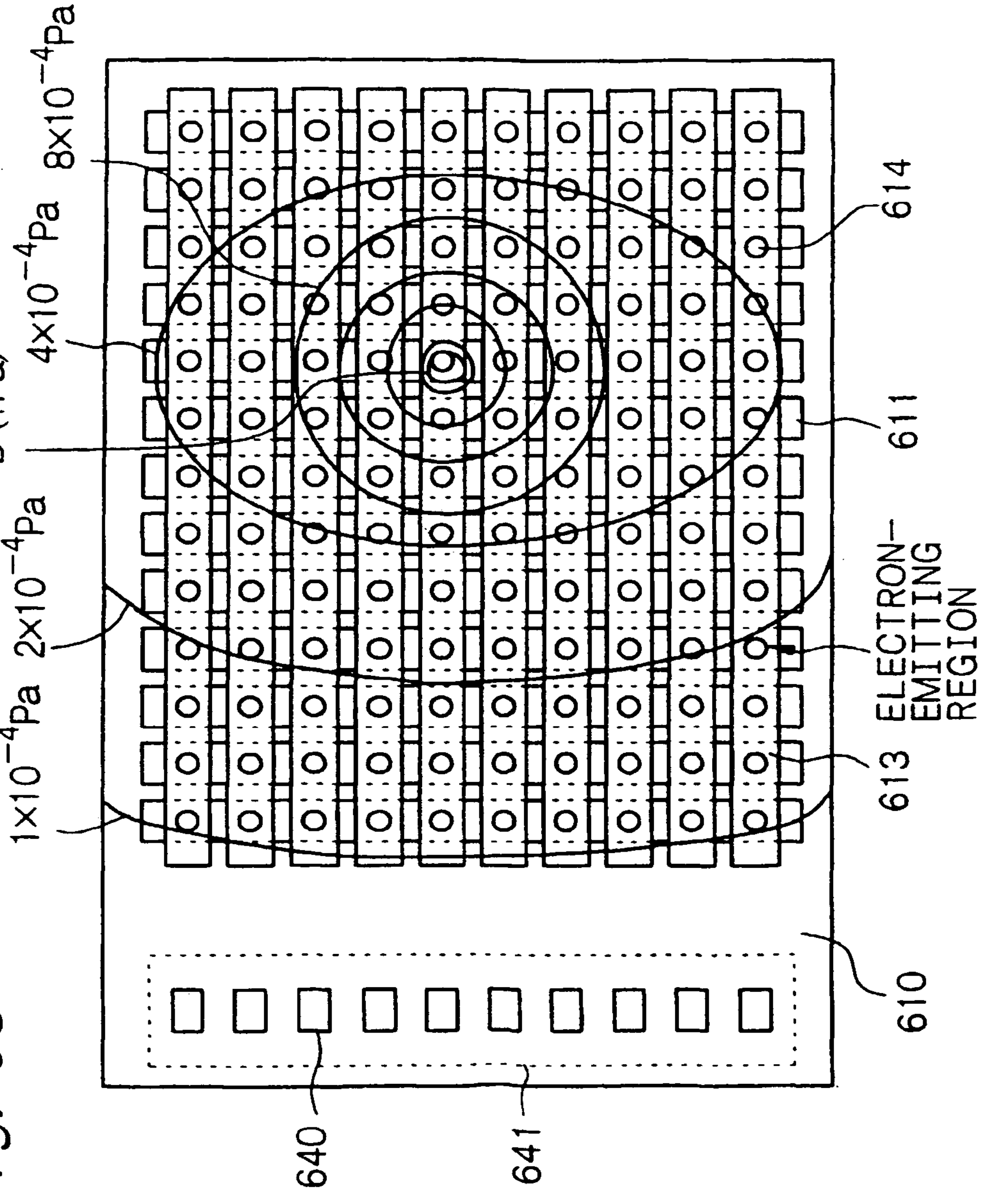


Fig. 68


8×10⁻⁴Pa
4×10⁻⁴Pa
D (1Pa)
2×10⁻⁴Pa
1×10⁻⁴Pa
614
611
ELECTRON-
EMITTING
REGION
613
610
640
641

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 100 107 A3

(12) # EUROPEAN PATENT APPLICATION

(88) Date of publication A3:
02.06.2004 Bulletin 2004/23

(51) Int Cl.7: **H01J 7/18**, H01J 29/94

(43) Date of publication A2:
16.05.2001 Bulletin 2001/20

(21) Application number: **00403155.5**

(22) Date of filing: **13.11.2000**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **12.11.1999 JP 32330199**
15.11.1999 JP 32408899
31.08.2000 JP 2000262754

(71) Applicant: **SONY CORPORATION**
Tokyo (JP)

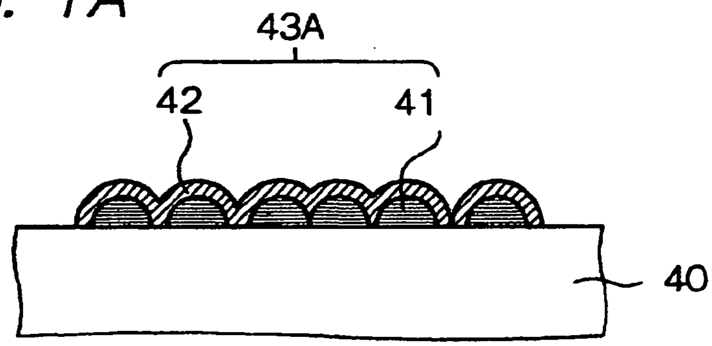
(72) Inventors:
- **Morikazu, Konishi, c/o Sony Corporation Shinagawa-ku, Tokyo (JP)**
- **Ichiro, Saito, c/o Sony Corporation Shinagawa-ku, Tokyo (JP)**
- **Masakazu, Muroyama, c/o Sony Corporation Shinagawa-ku, Tokyo (JP)**

(74) Representative: **Thévenet, Jean-Bruno et al**
Cabinet Beau de Loménie
158, rue de l'Université
75340 Paris Cédex 07 (FR)

(54) **Getter, flat-panel display and method of production thereof**

(57) A getter (43A) comprising a support member (41) which is formed on a substratum (40) and which has a convexo-concave surface or is constituted of a porous material member, and a gas-trapping layer (42) formed on the support member in conformity with the surface of the support member.

Fig. 1A



EP 1 100 107 A3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 40 3155

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X Y	US 5 520 563 A (WALLACE ROBERT M ET AL) 28 May 1996 (1996-05-28) * column 5, line 24 - line 44 * * column 5, line 62 - column 6, line 24 * * column 34 - column 38 *	1 3	H01J7/18 H01J29/94
Y	EP 0 275 844 A (GETTERS SPA) 27 July 1988 (1988-07-27) * claim 1 *	3	
Y	WO 99/00822 A (MOTOROLA INC) 7 January 1999 (1999-01-07) * page 9, line 22 - page 10, line 10 * * page 11, line 17 - page 12, line 3 * * page 15, line 21 - line 30 *	1,2	
Y	WO 95/23425 A (GETTERS SPA) 31 August 1995 (1995-08-31) * page 3, line 28 - page 5, line 2 * * page 6, line 10 - line 14 * * page 9, line 21 - page 11, line 17; claims 1,7 *	1,2	TECHNICAL FIELDS SEARCHED (Int.Cl.7) H01J
X	US 5 689 151 A (CHO CHIH-CHEN ET AL) 18 November 1997 (1997-11-18) * column 5, line 5 - line 43; claims 1-14 *	1,3,4,19	
X	US 5 656 889 A (ITOH SHIGEO ET AL) 12 August 1997 (1997-08-12) * claims 1,2; figure 4 *	4	
X	US 5 865 658 A (WATKINS CHARLES MARTIN) 2 February 1999 (1999-02-02) * claims 1-11 *	19	

-/--

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	6 April 2004	Van den Bulcke, E

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03 82 (P04C01)

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 40 3155

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 5 578 900 A (PENG CHAO-CHI ET AL) 26 November 1996 (1996-11-26) * claims 1-20 *	4,5,7, 15, 19-21, 23,24, 31,32,34	
A	JP 63 181248 A (MATSUSHITA ELECTRIC IND CO LTD) 26 July 1988 (1988-07-26) * abstract *	4,5	
A	WO 98/43269 A (GETTERS SPA) 1 October 1998 (1998-10-01) * claims 1,11,15,16 *	19,23	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	6 April 2004	Van den Bulcke, E

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

European Patent Office

Application Number
EP 00 40 3155

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☒ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

European Patent Office

LACK OF UNITY OF INVENTION SHEET B

Application Number
EP 00 40 3155

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-3

   describe the construction of a getter with porous material and a gas-trapping layer

   ---

2. claims: 4-18

   describe a flat-panel display with a first and second panel and a getter. The getter is described with a statement of an effect to maintain a vacuum between the two panels. No real feature of the first independent claim 1 is given in the second independent claim 4

   ---

3. claims: 19-38

   describe a method of producing the flat-panel display of the claims 4-18. The third independent claim 19 does also not include any feature of the first independent claim 1

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 00 40 3155

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

06-04-2004

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 5520563	A	28-05-1996	US	5453659 A	26-09-1995
			EP	0686992 A1	13-12-1995
			JP	8171877 A	02-07-1996
EP 0275844	A	27-07-1988	IT	1201540 B	02-02-1989
			DE	3786779 D1	02-09-1993
			DE	3786779 T2	18-11-1993
			EP	0275844 A2	27-07-1988
			IN	169971 A1	18-01-1992
			JP	1962255 C	25-08-1995
			JP	6087402 B	02-11-1994
			JP	63182283 A	27-07-1988
WO 9900822	A	07-01-1999	US	5945780 A	31-08-1999
			TW	381282 B	01-02-2000
			WO	9900822 A1	07-01-1999
WO 9523425	A	31-08-1995	IT	1273349 B	08-07-1997
			CA	2174962 A1	31-08-1995
			CN	1136364 A ,B	20-11-1996
			DE	69517019 D1	21-06-2000
			DE	69517019 T2	18-01-2001
			EP	0748513 A1	18-12-1996
			WO	9523425 A1	31-08-1995
			JP	3103115 B2	23-10-2000
			JP	9509525 T	22-09-1997
			KR	234857 B1	15-12-1999
			RU	2137245 C1	10-09-1999
			US	6042443 A	28-03-2000
			US	5934964 A	10-08-1999
US 5689151	A	18-11-1997	NONE		
US 5656889	A	12-08-1997	JP	3430560 B2	28-07-2003
			JP	7029520 A	31-01-1995
			JP	3396912 B2	14-04-2003
			JP	7029521 A	31-01-1995
			FR	2709373 A1	03-03-1995
			KR	139489 B1	01-06-1998
			US	5835991 A	10-11-1998
US 5865658	A	02-02-1999	US	5973445 A	26-10-1999
US 5578900	A	26-11-1996	NONE		
JP 63181248	A	26-07-1988	NONE		

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 00 40 3155

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

06-04-2004

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9843269 A	01-10-1998	IT MI970701 A1	25-09-1998
		CN 1220766 A	23-06-1999
		CN 1220766 T	23-06-1999
		EP 0907959 A1	14-04-1999
		WO 9843269 A1	01-10-1998
		JP 2000516389 T	05-12-2000
		KR 2000015982 A	25-03-2000
		RU 2199790 C2	27-02-2003
		TW 382734 B	21-02-2000

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82